VEHICLE EXTRICATION

Extrication operations on today's vehicles are significantly different and more dangerous than what we have faced in the past. The government is requiring that auto makers adhere to tougher, more stringent safety standards. These safety standards increase the survivability of passengers that have been involved in an accident, at the same time we are finding that the vehicles manufactured to these newer standards are presenting us with tougher challenges. These vehicles are now being armed with multiple airbags that are controlled by smart computer system which can be extremely dangerous to rescuers and patients during extrication operations.

Firefighters will also find that automakers are using more exotic metals to strengthen and reinforce vital structural components. In the past, we have gone to the scene of an extrication knowing that our tools, regardless of the brand, could cut through any vehicle we came up against. Today, however, because of these stronger, more lightweight metals, the tools that we have relied on in the past are having a tougher time cutting through and spreading these metals. Never before has it been so important to understand the capabilities and limitations of our rescue tools. Rescuers will have to find alternative techniques and tools to achieve the same results as in the past. Understanding how vehicles are constructed and knowing what they are constructed of, will allow us to make better decisions on scene

Rescuers must also understand that the auto makers are constantly improving on the designs of their safety systems. These changes are happening so quickly, that it would be safe to say that by the time this chapter and volume are published, the material you are reading will outdated. Extrication tool manufactures are trying to stay ahead of all of these improvements and innovations. For this reason, rescuers must continue to educate themselves on the constantly changing innovations being used on today's vehicles.

In this chapter, we will discuss numerous topics involving vehicles and extrication. We will cover passenger safety systems, including airbags, rollover protection systems and their components. We will also talk about hybrids, alternative fuel vehicles and their associated dangers to firefighters. From there, we will move on to the actual extrication evolutions, beginning with the tools we commonly use in extrication, stabilization techniques, tips and rules for extrication, and step by step instructions on the various extrication techniques.

PASSENGER SAFETY SYSTEMS

When we think of passenger safety systems, the one thing that usually comes to mind is the vehicle's airbags. We tend to forget that airbags are only one part of an entire system designed to protect the vehicle's passengers. These systems also comprise other safety components that rescuers tend to over look, such as roll bars and seat belt pre-tensioning systems just to name a few. Knowing what these components are designed to do and how they work will help the fire fighter operate safely and efficiently.

In this section, we will discuss these components as well as the potential dangers that firefighters can face while operating in and around them. We will begin by talking about new vehicle design and the exotic metals used to strengthen today's cars, trucks and minivans. We will then move on to the history and evolution of the airbag and how they function, as well as the many airbag possibilities in

today's vehicles. From there we will discuss seat belts and their pre-tensioners. We will also discuss the roll over protection systems to include the roll bars that protect passengers of convertibles in the event of a roll over.

VEHICLE DESIGN

The design and manufacturing of the automobile has undergone an amazing evolution. From the day the first car hit the streets to the high tech vehicles that are being driven now, the auto industry has constantly worked at putting better, stronger, more fuel efficient vehicles on the road. In order to accomplish this, new manufacturing techniques, designs and metals have been produced that have not only made vehicles safer, but have also created extrication challenges for rescuers. In this section we will concentrate on vehicle designs and the metals used today that encapsulate the vehicles passengers in a formidable safety cage.

During the early years, few auto makers thought of the safety of passengers in their vehicles. The majority of the auto industry seemed more concerned with the aesthetics of their vehicles and designed their cars to meet these needs. The common thought of the time was that if cars were "built like tanks", the passengers would naturally survive an accident. These ideas have since changed, crumple zones have since been integrated into a vehicle at strategic locations. The metals being used are now designed to distribute the impact energy to the rest of the vehicle instead to the passengers. These systems, along with others, have drastically reduced the mortality rate of vehicle accidents.

Crumple Zones

The purpose of a crumple zone is to increase the amount of time it takes the car to come to a complete stop and absorb impact energy when involved in a frontal collision. This is known as the vehicle's deceleration time. By increasing the time it takes for your car to come to a stop after you hit the object, the force is spread over a longer period of time, by a longer period, we mean milliseconds. Crumple zones work by managing crash energy, absorbing it within the forward section of the vehicle, rather than being directly transmitted to the occupants, while also preventing intrusion into or deformation of the passenger cabin. This achieved by controlled weakening of outer parts of the car while strengthening the inner part of the body of the car, the passenger cabin, by using more reinforcing beams and higher strength steels.

The secondary purposes of crumple zones are to slow down the collision and to absorb energy. For example, the difference between slamming someone into a wall headfirst (fracturing their skull) and shoulder-first (bruising their flesh slightly) is that the arm, being softer, has tens of times longer to slow its speed, yielding a little at a time, than the hard skull, which isn't in contact with the wall until it has to deal with extremely high forces. Seat belts also help absorb energy by being designed to stretch during an impact. In short: A passenger whose body is decelerated more slowly due to the crumple zone over a few milli-seconds, survives much more often than a passenger whose body indirectly impacts a hard, undamaged metal car body which has come to a halt nearly instantaneously.

The final impact after a passenger's body hits the car interior, airbag or seat belts, is that of the internal organs hitting the ribcage or skull. The force of this impact is the mechanism through which vehicle accidents cause disabling or life threatening injury. The sequence of energy dissipating and speed reducing technologies - crumple zone - seat belt - airbag, are designed to work together as a system, to reduce the force of this final impact.

A common misconception about crumple zones is that they reduce safety by allowing the vehicle's body to collapse, crushing the occupants. In fact, crumple zones have reduced mortality and injuries

and are typically located in front and behind of the main body (though side impact absorption systems are starting to be introduced), of the car (forming a rigid safety cell). The marked improvement over the past two decades in high speed crash test results and real-life accidents should also erase any fears pertaining to crumple zones. Modern vehicles using crumple zones provide far superior protection for their occupants in severe wrecks than older models. Older "tanks" have a much faster deceleration time than newer vehicles resulting in greater impact forces being distributed to the passengers which causes greater inuries to those passengers.

The crumple zone on the front of these cars absorbed the impact of a head-on collision. If there were no crumple zones, the passengers would end up absorbing the energy of this impact.

The picture below shows the crumple zones in the rear and the hood of the vehicle. The crumple zone of the hood causes the the hood to deform so that it does not detach and fly through the windshield and into the passenger's compartment.

Exotic Metals Used Today's Vehicles

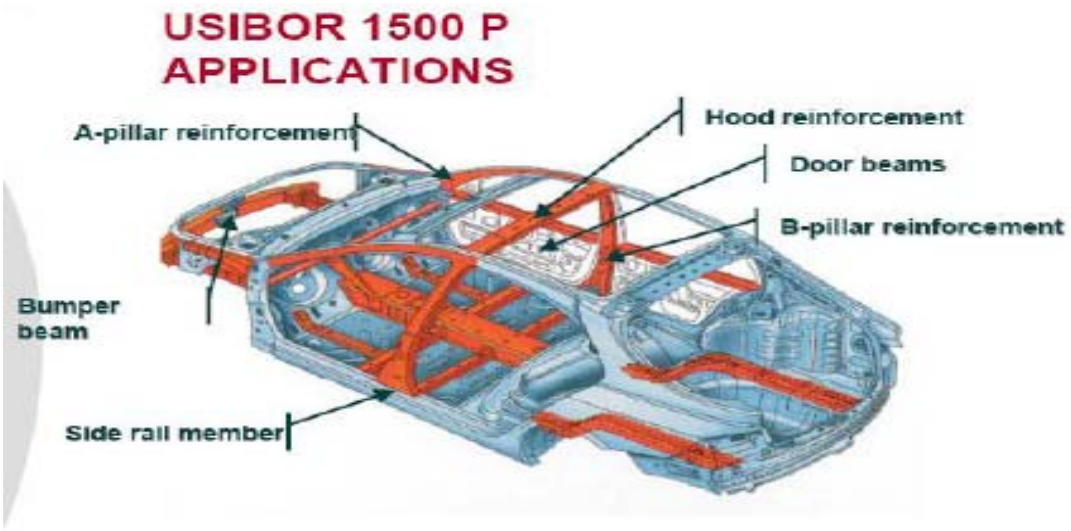
The National Highway Traffic Safety Administration (NHTSA) has a legislative mandate to issue Federal Motor Vehicle Safety Standards (FMVSS) and Regulations to which manufacturers of motor vehicle must conform and certify compliance. FMVSS 209 was the first standard to become effective on March 1, 1967. A number of other FMVSS became effective for vehicles manufactured on and

after January 1, 1968. Subsequently, other FMVSS have been issued. New standards and amendments to existing standards are published in the Federal Register.

These Federal safety standards are regulations written in terms of **minimum** safety performance requirements for motor vehicles or items of motor vehicle equipment. These requirements are specified in such a manner "that the public is protected against unreasonable risk of crashes occurring as a result of the design, construction, or performance of motor vehicles and is also protected against unreasonable risk of death or injury in the event crashes do occur."

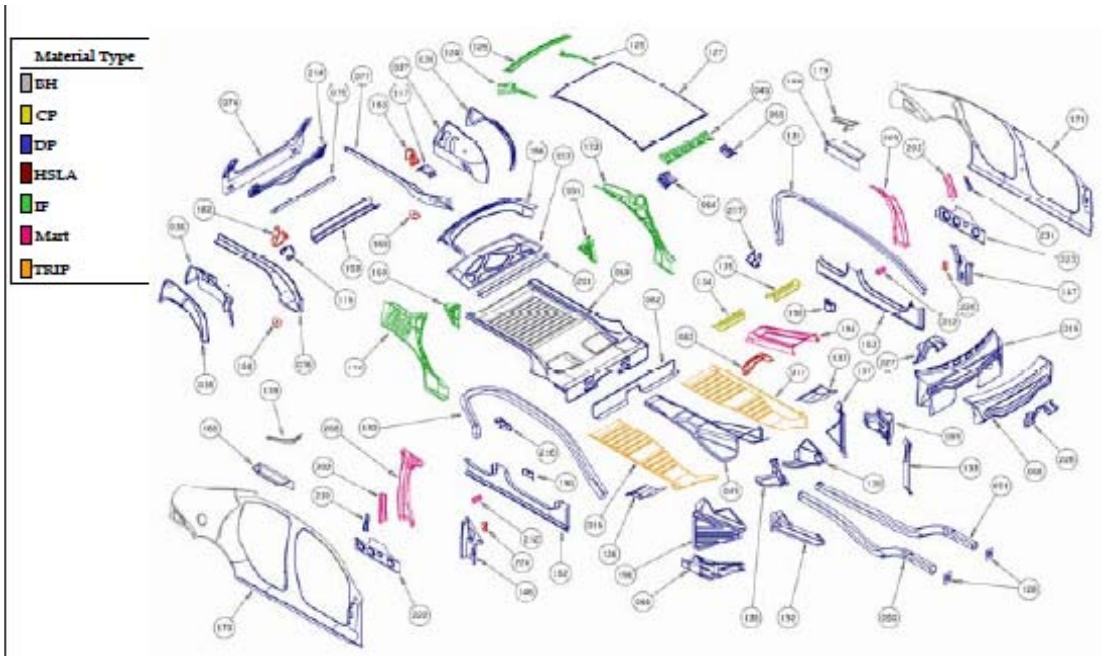
There are a few standards specifically mandatng that vehicles meet minimum requirements to protect passengers in a crash. In order to meet these requirements, auto makers had to strengthen their vehicle's main structural supports. Normally this would mean heavier and more metals for reinforcement. However, with today's technology, automakers are able to use stronger, lighter weight metals that will definitely test the limits of the tools we carry on our trucks. These new Advanced High Strength Steels (AHSS) began by incorporating elements such as Ferrite and Martensite as some of the first generation High strength dual phase steels. As more advancements came along, newer steels, such as Twinning Induced Plasticity (TWIP) steels added more strength for added patient protection. These steels were also more flexible than older steels which had the added affect of distributing the energy of an impact throughout the vehicle versus concentrating that energy on the point of impact. As technology progressed, Boron and other elements were incorporated into the steel making process of Advanced High Strength Steels that dramatically increased the strength of a vehicle.

These newer metals are not used on the entire vehicle; instead they are used in the areas that encapsulate the passengers. These areas usually comprise the posts, roof support structure and parts of the floor structure. Unfortunately, these are the areas where we normally place our tools. The rest of the less vital areas of the vehicle can be made of the more brittle, lower strength steels. The picture below illustrates the more common places that some of the AHSS are used. USIBOR and BTR are trade names for Boron that are specific to the country that produces it.



The brown areas in the picture above show how this vehicle's front passenger compartment is reinforced with AHSS steels in the A & B posts, side impact bars on the doors, the bar that reinforces the dash area, the rocker panels and floor structure. The challenge for firefighters is to cut into parts of the vehicle that aren't reinforced.

This next picture is a good illustration of the different metals used to make up the vehicle. Every part of the vehicle is designed to do a specific task. Each part is made from a specific alloy material with a specific thickness. It is impossible to determine the type of material or the hardness of the material by just looking at it.

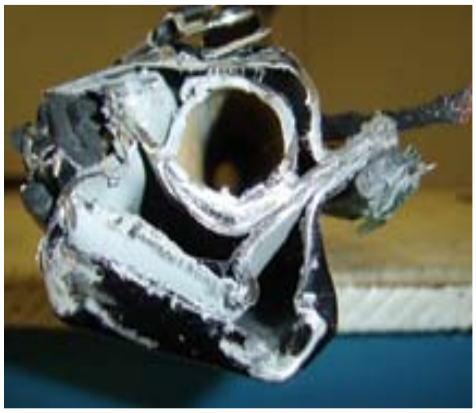


B Posts

Side impacts are still the leading cause of death in motor vehicle crashes. Automakers are greatly increasing the strength of the B-Post area and floor section of the vehicle. Because of the increase in strength, the B-Post is becoming more difficult to cut.

In this picture, we see how some manufacturers are strengthening the posts in order to meet the requirements of the new safety standards set to be put in place in 2010.

Some of us will experience a lot of difficulty when attempting to cut through these posts. Some tools, such as combi-tools, will not have sufficient cutting force to cut through these posts. Different methods and tools will need to be employed when attacking these areas. It is also important for rescuers to understand that these types of reinforcements are not exclusive to high priced vehicles. The preceding picture was from a 2010 Mitsubishi Galant. The pictures below show strengthening techniques in other vehicles. These areas of the vehicle are heavily reinforced, designed to stay rigid and direct the collision forces around the passenger compartment.



The left picture on the preceding page is of a Mercedes B-Post and the picture on the right is a Subaru B-Post. Each of these posts will require a cutting force in excess of 200,000 lbs to cut through. The Advanced High Strength Steel reinforcement in the center of each post will not cut, but will fracture when enough force is applied. The round shape of the reinforcements can cause hydraulic cutters to lay over and the blades to separate. When the blades separate there is an excessive amount of lateral force applied to the blades, increasing the chances of the blade failing and breaking.

The following pictures show how other auto manufacturers are dealing with the more stringent safety standards of 2010. As you can see, some posts have more reinforcement than others, but all represent a tough challenge for today's rescuers. The picture on the bottom right is of a B post at the rocker panel area.

High strength aluminum is also being used for its strength. There are a few Aluminum Auto Bodies such as the Honda Insight, Jaguar XJ-Aluminum, and Audi A8 on the road today. There are even some "Hybrid" vehicle structures such as the 5-series BMW which uses an aluminum structure in front of the firewall and a steel structure from the firewall back.

Foams are also used to add structural support and reduce Noise, Vibration, and Harshness (NVH) in some late model cars. Cadillac's use this foam extensively throughout the vehicle; this is why it is one of the quietest vehicles on the market. When these foams melt or burn they release a tremendous amount of toxic gasses. Structural foam is extremely strong while being extremely light weight. Many structural parts of the vehicle are being filled with these foams which make them difficult to cut.

All the innovations used in today's vehicles represent the latest and greatest technologies on the market. As the safety standards become more stringent, stronger and more lightweight metals will be developed requiring newer, stronger tools. Staying abreast of all the new changes and knowing the limitations of your tools will ensure that rescuers make the best decisions when it comes to choosing which evolution is to be used.

AIRBAGS

A Brief History

The airbag was first seen in vehicles in the mid 70's and can arguably be the most significant safety advance since the invention of the seatbelt. However, people felt that their chances of survival depended on how rugged their vehicles were, not on seat belt usage, so there was an extremely low rate of seatbelt use. Soon thereafter, automakers felt that some sort of passive restraint system was necessary to protect vehicle occupants. This passive system would not require any action by vehicle operators to activate the system, compared to the seat belt that requires the operator to actively buckle up.

Even though vehicles were equipped with airbags, the mortality and morbidity rate increased. This was because airbags were being marketed not as part of a system to be used in conjunction with seat belts, but as an alternative to seatbelt use. The success of the airbag marketing campaign led people, even faithful seat belt users, to believe that seat belts were no longer necessary. An unfortunate fact was that the airbags were extremely ineffective at keeping the vehicle's occupants in their seats. Rescuers were finding patients either thrown from the vehicle, down in the floor board area, or thrown into another part of the car. Soon after, another major campaign would emphasize the importance of using the seat belt in conjunction with the air bags. The real efficacy of the airbag was now evident; people were walking away from the type of accidents that before would have meant sever injury or certain death.

In 1980, Mercedes Benz began offering frontal airbags as an option, but it wasn't until 1987 that they became standard in some European and Japanese, followed by the American auto makers in the early 1990's. In 1998, the National Highway Traffic Safety Administration, (NHTSA), a division of the U.S. Department of Transportation, created the Federal Motor Vehicle Safety Standard (FMVSS) 208,

which required that all new vehicles be equipped with dual frontal airbags. This standard was later amended to state that all vehicles manufactured after January, 2007 be equipped with de-powered or dual stage airbags. The objective of this standard was to reduce injuries to smaller adults and children caused by the higher powered, single stage airbags. Since its inception, this standard has undergone a number of revisions in an effort to make airbags safer and more efficient. One thing is certain, airbags are doing their job; the death rate from frontal collisions alone has decreased by 30 %.

Parts of an air bag system

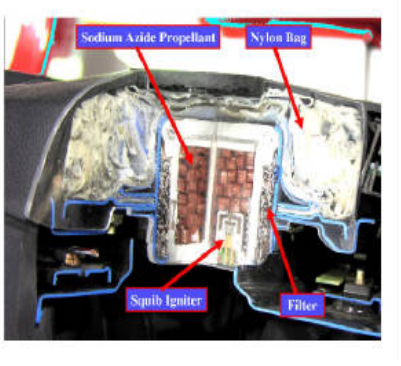
Air bags and their systems are constantly evolving into safer and more efficient systems. This same efficiency, plus the increased number of air bags in any given vehicle, has made our job all the more dangerous. Without a doubt, the most visible component, and the one that garners the most attention, is the air bag. Not knowing what makes up an entire system, vehicle occupants attribute the airbag as the single component that saves lives. There is, however, a lot more to the system than just the airbag. The entire safety system could be broken into four basic parts: the air bag module, the Electronic Control Unit, the crash sensors and the airbag on/off switch. In order to fully be aware of the dangers that air bags present to firefighters, we need to have at least a basic understanding of the entire system and how they work. In this section we will discuss the components of a vehicle's supplemental restraint system (SRS).

1. Air bag module

The air bag module consists of three basic components: the air bag, the inflator and igniter or inflator squib. The air bag is made of a thin nylon fabric which is folded into its compartment. The inside of the bag is coated with a light film of some sort of talcum powder that is meant to keep the bag from sticking together on deployment. This powder usually fills the patient compartment when the bags are deployed. This is why most occupants think that the vehicle is on fire right after an air bag deployment. The air bag comes in many different sizes and shapes, depending on its intended function. *All* air bags present an extreme danger to the unprepared or unwary firefighter. The different types of airbags, along with their associated dangers, will be discussed later in the chapter.

The second component of the air bag module is the inflator. The two types of inflators can be either the solid propellant type or the pressurized gas cylinder type. The solid propellant inflator uses either sodium-azide or nitro cellulose as the propellant. These chemicals have the explosive properties necessary for extremely fast deployment and, as such, are used in frontal and some side impact airbags in older vehicles. They also have the associated danger of releasing a tremendous amount of heat when they are ignited. For this reason, these airbags are usually vented to allow the heat to escape.

The following pictures show the typical solid propellant inflator system. The photo on the left is inflator from a steering wheel air bag. The left is the type of inflator found in a passenger dash mounted frontal airbag



The picture below on the left shows a front and rear view of a steering wheel mounted single stage air bag. The photo on the right is the rear view of a passenger dash mounted dual stage frontal airbag:

There is another danger in some steering wheel mounted airbags that occurs during vehicle fires. On some older vehicles, the screw holes, used to mount the inflator, weaken and expand with direct flame impingement. The casing and screw mounts of these inflators were made of an aluminum alloy that weakens during fires. The heat from the fire would cause the propellant to ignite which then caused the casing to bust free from its mount and become a high speed projectile. Often times, this would shoot free with enough force to shoot out through the roof and still have enough energy to travel more than a hundred feet. The hazard to rescuers is obvious.

The picture below shows the area that weakens during a fire.

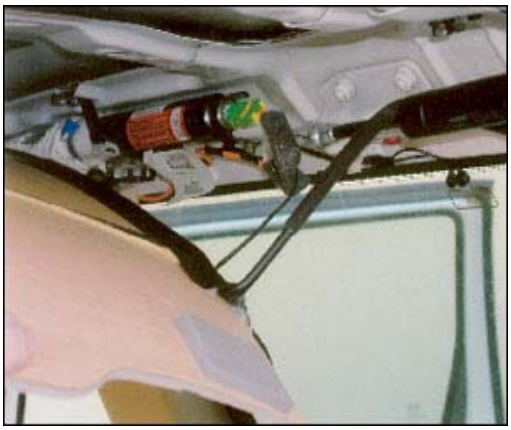
This next picture shows the aftermath of a dislodged propellant casing that has gone through the roof of its vehicle.

The second type of inflator, the stored pressure gas inflator, is usually used for head curtain, side impact and other specialty bags. They are filled with an inert gas such as argon, helium or nitrogen that is used to inflate the airbag once a firing signal is sent. These cylinders are typically pressurized anywhere from 1400 to 3000 psi, however some newer systems have cylinders pressurized significantly higher.

The danger with these pressurized cylinders is significant. As stated before, these pressures can be as extremely high. These cylinders can become high speed projectiles if they are accidentally cut with hydraulic cutters. They can either shoot completely through a vehicle, endangering anybody on the outside, or they can ricochet around the inside. They have the ability to travel quite a distance, with the potential to cause severe injury or death. What makes them even more dangerous is their placement. There is no industry standard on mounting locations, so it becomes extremely important to search for these cylinders prior to performing any extrication evolutions. The lack of a mounting standard becomes even more of a problem due to the fact that the cylinders are sometimes mounted in the exact areas of the vehicles where we will be doing most of our work.

The following pictures show some of the common mounting locations:

Roof mounted cylinders:



The arrow on the picture below left shows the roof mounted cylinder on the passenger side. On the right, the arrow shows the un-deployed driver side cylinder of the same car. A fire fighter making a pie cut into the roof above this B post is taking a chance of cutting through the cylinder.

Post mounted cylinders:

A post

Some rescuers think of the A post as the portion that only goes from the dash to where it connects to the roof rail. Rescuers need to understand that the A post continues all the way down to meet at the rocker panel. This is a vital part of the structural support and is another place to mount a cylinder, as shown in the previous picture. This type of mounting is common for head impact tubular air bags. An important point to remember with this mounting is that this area is where we make relief cuts for dash displacement evolutions, such as the dash roll or lift. If we plan to perform either of these evolutions it is crucial that we expose the A post all the way down to the rocker panel and into the kick panel. Once this area has been exposed and the cylinder is located, we can make our necessary relief cuts.

B post

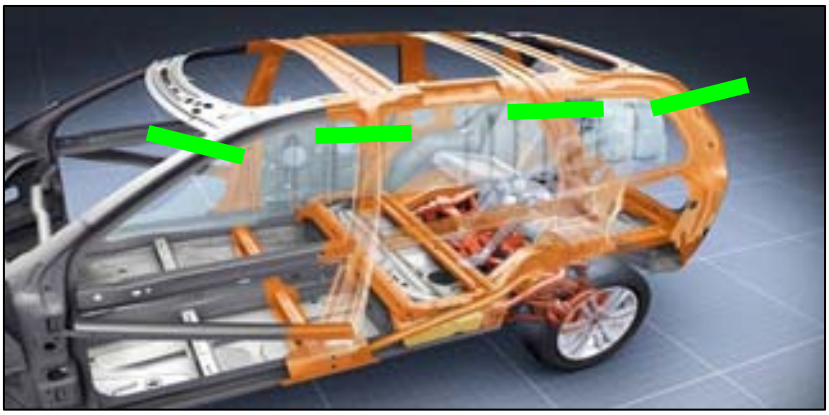
Here, we have a cylinder mounted in the lower portion of the B post. This cylinder is responsible for deploying the seat mounted side impact air bag. Another possible location for seat mounted airbag cylinders is in the seat back itself. The cylinder is mounted underneath the folded bag, usually in the upper third portion of the seat. This can present us some problems if we attempt to cut the seat back away from the seat. Once we have identified that there is a seat mounted air bag, we should cut through the side panel material of the seat to expose the bag and the cylinder. After this is done, we can cut the seat back out if necessary.

C Post

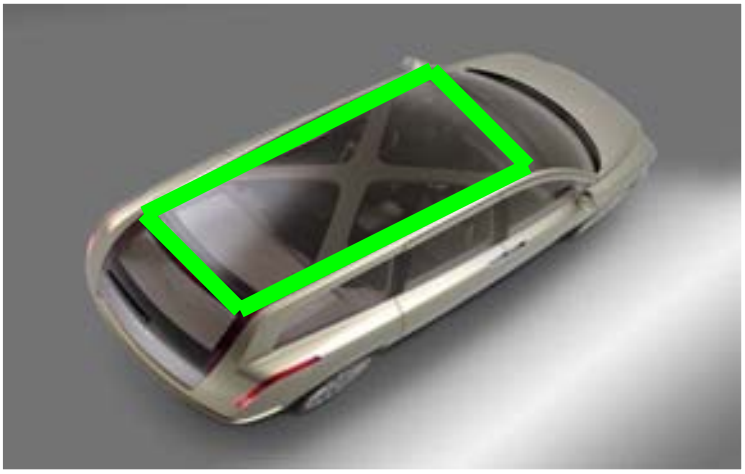
Cylinders mounted in the C post are usually placed in lower, thicker portion of the post. But, because of the lack of an industry mounting standard, this can never be taken as an absolute. Cutting high on the post usually keeps rescuers out of danger while at the same time letting your cutters attack the smallest portion of post. Cutting through the tubing that leads from the cylinder to the air bag is safe; this will not cause the cylinder to release the pressurized gas.

Another important point to note is that if you look where the cylinders are mounted, you'll notice that they are always mounted in straight portions of the posts or roof rails. Pressurized cylinders are always straight and never manufactured to follow the curves or bends in the vehicle's posts and roof rails; they would loose their strength and their ability to hold such high pressures. Rescuers can use this knowledge to help them with their tool placement. If we are not able to expose the posts to look for the cylinders, we should be able to cut through the straight portion of the posts at the area where they meet the roof rail. This should keep us out of the areas where cylinders might be mounted. Using pie cuts into the roof rail can no longer be considered a safe method because of the possibility of a cylinder being mounted along the roof rail right above the post. Of course, the only way to positively locate the pressurized cylinders is to peel as much of the plastic molding as possible

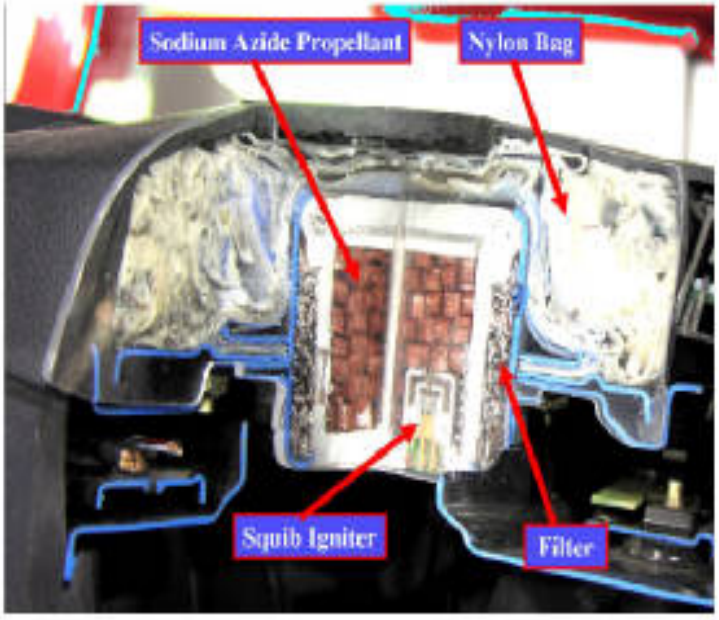
The green lines in the pictures below illustrate the ideal tool placement in the event that exposing the posts is not possible. By cutting in these areas, we should stay free from any post or roof mounted cylinders:



Below is another option for roof removal that does not involve cutting through the posts. Typically, a cut like this would require the use of a recip saw, a skill saw with a diamond blade or a circular cut-off saw with a metal cutting wheel.



The third portion of the air bag module is the squib. The inflator or igniter squib is the mechanism that receives the firing signal from the Electronic Control Unite, or ECU, and ignites the propellant or blows the cap on the pressurized cylinder. For frontal collision airbags in the steering wheel and dashboard, the squib is placed in a small compartment within the chemical propellant compartment as shown below.



In the pressurized cylinder, the squib is placed on the portion of the cylinder that the wiring is connected to. When the control module sends the impulse to the igniter, the igniter melts a small bladder, much like a coke bottle cap, inside the canister. The argon or nitrogen is then allowed to escape, filling the airbag. Like nitrogen, argon is totally harmless.

The picture below left shows the wiring on one end and the other end is where the bag connects to the cylinder.

The arrow in the above right picture shows the wiring going into the bottom portion of the cylinder. In this type of cylinder, the squib will be in the area where the wires connect into the cylinder.

2. Electronic Control Unit (ECU)

The ECU is the main controlling unit or the brain of the entire passenger safety system. The ECU not only sends the firing signal to all the air bags, but in the case of a smart air bag system, it controls the force at which some of those air bags are deployed. These control units are part of more advanced "smart" system that can sense whether the front passenger seat is empty, and if so, will keep the passenger air bag from deploying. The ECU also sends the signal to seat belt pretension devices and the rollover protection bars in convertibles. The control unit is constantly receiving sensory input from sensors mounted around the vehicle and makes the necessary calculations to allow it to deploy the appropriate safety systems.

The ECU is typically mounted in the center of the vehicle in an area that provides the best protection. Some of the first generation units had capacitors that could take approximately 20 – 30 minutes for the power to drain after the 12 volt battery was disconnected. Today's vehicles, however, have capacitors that drain within seconds. Care must still be taken, however, during extrication operations to ensure that the ECU is not damaged; this could inadvertently cause the ECU to deploy an air bag.

An even more advanced system senses the weight of the front seat passenger and can either deploy the air bag with more or less force, depending on the passenger's weight. One of the later amendments to the Federal Motor Vehicle Safety Standard (FMVSS) 208 requires that all vehicles manufactured after 2007 are required to be equipped with this type of system. The purpose of this type of system is to perform one of two functions, depending on the vehicle: keep the front passenger air bag from deploying if unoccupied, or sense the weight of the occupant in the front seat and deploy the air bag with less force if the passenger is smaller or with greater force for a larger person. Some systems are very simple and only sense the presence of a person on the seat, others can differentiate between a child, small adult or large adult.

This type of system, called an Occupant Classification System or "smart" system, uses sensors in the seat along with dual stage or de-powered frontal air bags. This "smart" system can also sense the severity of the crash using accelerometers, wheel speed indicators, brake pressure sensors and impact sensors in the vehicles to deploy the air bags with the appropriate force. Dual stage air bags are equipped two individual inflator units that can be deployed individually or both at the same time**.** If the ECU determines that the occupant is a heavier person or that the crash meets the criteria for a

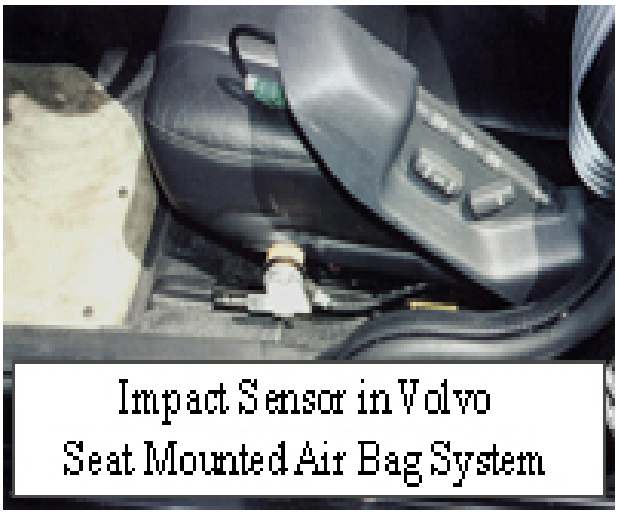
severe crash, both inflator units will fire. If the occupant is a smaller person or the crash is less severe, it only ignites one of the inflator units, leaving the second inflator unit un-deployed and loaded. The danger with this type of system is that if only one of the frontal air bag inflator units has been deployed, rescuers can falsely assume that that both air bags are no longer a threat. The fact is, we can have an inflator that is still loaded and ready to deploy the air bag.

The typical extrication scenario has one of the two front seats empty. A rescuer, seeing a deployed air bag, thinks that the vehicle is safe and enters the vehicle. The rescuer then places his or her knee on the unoccupied seat. Now the ECU senses the rescuer's weight and arms the second un-deployed inflator. The air bag, even though it has already deployed, is now ready to deploy for a second time into the unsuspecting rescuer. For this reason, it is especially important to disable the entire system by disconnecting the 12 volt battery. **Even if rescuers are able to disable the system, we must make every effort to keep ourselves and any patients out of all air bag deployment zones.**

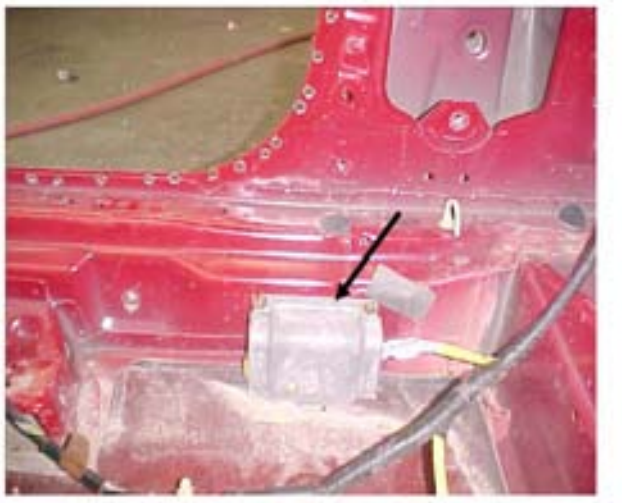
3. Crash Sensors

Crash sensors in today's vehicles are significantly more advanced than those in earlier model cars. Some of the older sensors were simple pressure sensors but have since progressed into highly advanced micro-machined accelerometers. The pressure type sensors were typically used in older vehicles and sensed the crushing forces of a crash. They could be mounted in a number of different places such as at the front of the vehicle near the bottom of the radiator support, at the bottom of a B post, in the door or door sill and even at the bottom of seat brackets.

Seat bracket mounted pressure sensor



B post mounted pressure sensor



With side impact pressure sensors, the possibility of accidental air bag deployment exists during extrication operations, even if the batteries are disconnected. These sensors are mechanical and safety devices that are in place with these systems can fail after a crash. The simple act of using hand tools to create a purchase point or removing the door with hydraulic tools can cause the air bags to deploy. As always, it is important that all rescuers are aware of this possibility and that all effort to protect themselves and the patient are exercised.

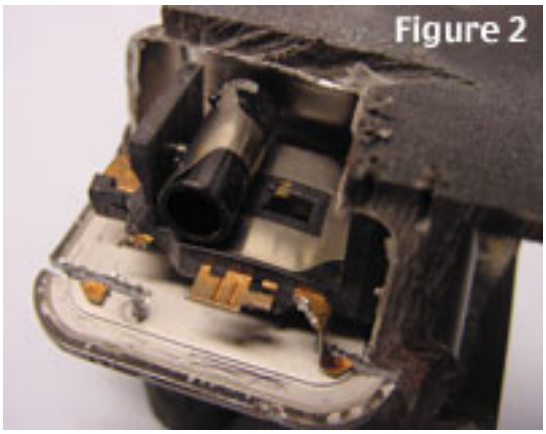
In newer vehicles, the type of sensor used is the micro-machined sensor. This type of sensor senses the extreme deceleration that takes place in a crash. They also sense how the vehicle is positioned with respect to the road. If the vehicle is moving too far out of the horizontal plane, as in a roll over, the sensors send the necessary information to the ECU which then triggers air bag deployment. These

sensors can be mounted in different areas of the vehicle but newer systems usually have more sophisticated sensors placed in the ECU.

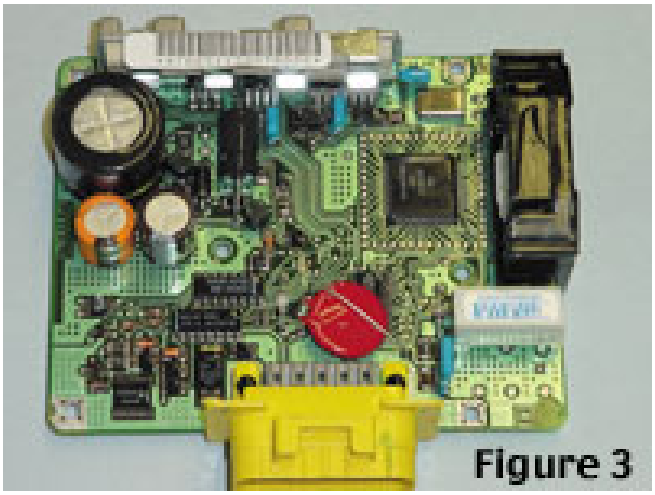
The following pictures show different accelerometer types of sensors:

Ball and magnet sensor

Spring band and roller design



Rotating weight design



4. Airbag on/off switch

These switches began to appear in vehicles around 1996 model vehicles. Some of the first models used keys to manually shut the passenger side front air bag off. Newer models are now turned on and off automatically using the sensors of the “smart” system. The purpose of this switch is to disable the passenger frontal airbag so that it does not deploy if a child or small adult is in that seat. The first systems were to be used so that children in car seats and small persons could sit in the front seat without the risk of injury due to a full force air bag deployment. Originally, these systems were used only on vehicles with little or no back seats but as “smart” systems came into development, these switches were used on all vehicles. Again, we risk injury if, in an automatic system, we place our weight on a seat when that system has been shut off. These air bags may now be live and loaded, if the battery has not been disconnected.

Types of air bags

With each new generation of vehicles coming out on the market, rescuers are finding that these vehicles are being equipped with more airbags. All of these air bags are designed with a specific purpose and function but when used in conjunction with the other safety systems, increase the survivability of all occupants involved in a vehicle accident. In this section, we will discuss the different types of air bags, the intended function and the danger that they present to rescuers.

1. Frontal air bags

These are the most prevalent and familiar air bags on vehicles. This is the only type of air bag that is on every vehicle that is equipped with air bags. There may not be a head curtain air bag or side impact bags, but if the vehicle has air bags, it will be equipped with frontal air bags. The purpose of the frontal air bag is to prevent any front seat occupant from impacting the steering wheel or dash board in the event of a frontal collision.

The first version of the frontal air bag was a single stage air bag with only one firing unit. It provided an added measure of safety for all passengers but created a hazardous situation for shorter drivers. In order for the frontal air bag to be effective, it has to have enough room to fully deploy prior to the driver impacting the bag. This ensured that the air bag's deployment energy was completely dissipated before the patient came into contact with the airbag. Obviously, a shorter driver has to move the driver's seat closer to the steering wheel in order to drive. This proved to be very dangerous and sometimes fatal. The driver usually made contact with an air bag prior to complete deployment and absorbed a lot of the energy. This is the point where injuries and fatalities occurred, usually dut to brain damage or fractured cervical vertebrae. Another danger with first generation frontal air bags is that they were extremely unreliable. That, coupled with the fact that some did not have any labeling or identification gave rescuers the idea that these airbags were not present. If the 12 volt battery was not disconnected, the system remained armed.

To combat these hazards, an amendment to FMVSS 208 mandated that vehicles manufactured in 2007 and later be equipped with an Occupant Classification System to work in conjunction with dual stage or de-powered frontal air bags, as discussed before in the Electrical Control Unit section. Some older model vehicles were equipped with this system long before the standard dictated. These air bags, however, are difficult if not impossible to differentiate from single stage air bags. The rescuer will not know whether the deployed frontal air bag is a single or dual stage type. The following pictures illustrate some frontal airbags.

Here we have a typical un-deployed steering wheel mounted single stage frontal air bag.

These pictures show the front and rear views of single and dual stage steering wheel air bags. The picture on the left shows that there is no ID stamp that will help rescuers differentiate a single stage from a dual stage bag. Even from the rear it is difficult to differentiate the two. In the picture on the right, the left module is the dual stage, the right having only one igniter squib is the single stage. Rescuers will not have this view to make the identification.

This picture shows the deployed first stage of a dual stage air bag. Even with this view, it is difficult to tell if both stages have fired.

Here, we have an un-deployed dual stage passenger frontal airbag. With this airbag, there are two separate distinct propellant units.

2. Head protection bags

One of the first types of head protection to be introduced in the US was the (HPS) Head Protection System in the 1998 BMW, also known as the (ITS) Inflatable Tubular Structure. These are much different than the curtain airbags we see in most vehicles. This tube is anchored at the pressurized cylinder that is mounted on the lower portion of the A post and at the rear to the roof rail behind the B-post, allowing it to deploy diagonally across the window opening. The bag is stored inside the trim of the A-post, along the headliner trim over each door. When un-deployed, the only identifying markings are the letters 'HPS' embedded in the trim cover at the top of the A posts. Unlike other airbags, the tubular bag consists of a specifically designed material that is woven in a pattern that expands as the bag deploys to form an airtight tube. Also unlike most airbags, the tube does not deflate; there are no vent holes that allow the gas to escape. The tube will actually remain inflated for hours after the collision. The tube remains firmly inflated to offer head protection from rebound forces, which are common in side impacts and rollovers. Once the door is opened, rescuers can safely puncture the tube and cut the mounting strap at the B post to get the bag out of their way. The bag is approximately 38 inches long and 5 inches in diameter when inflated. Nylon web straps are sewn into each end of the bag to attach it to the vehicle. Like all side impact airbags these can not deploy a second time. **If the tube is not deployed rescuers must not only stay out of the deployment zone of the tube, but the whole door area. These tubes are always used in conjunction with a torso type door or seat mounted airbag.**

The gas inflator is located at the front end of the system. The canister which is filled with nitrogen, argon or other inert gas is mounted in the dash at the lower A-pillar area. These systems will deploy if the sensor experiences an impact of about 12 mph or above. As stated before the cylinder of a tube can always be found in the lower portion of the A post. This location is in close proximity to where we will make relief cuts for the different dash displacement evolutions. It is imperative that we make sure to peel all the plastic from this area to ensure that we do not cut through these cylinders.

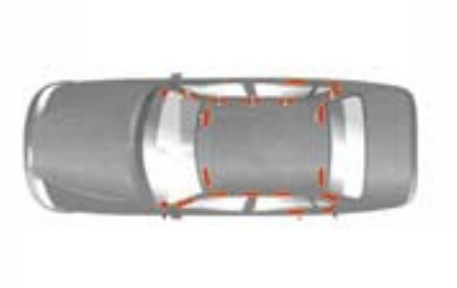
Side Curtain Airbags

The two most commonly used curtain airbags are the front window type and the full length type. The front window curtain usually extends from the A post to the B post and extends down from the roof to about the top of the door panel.

The full length curtain usually extends from just behind the A post to the C or D posts and extends from the roof to the top of the door panel also. Like the head protection tube, both of these are hidden behind the trim panels and head liner, when undeployed they can only be detected by small emblems embedded in the trim panels.

Rescuers must be aware that these emblems only indicate the presence of a head curtain bag, not the location.

These bags are deployed by small stored gas inflators that can be located at the front, center, rear, or anywhere along the support system. They are found in the A post, along the roof rails, in the C or D posts and some even over the rear glass.



It is extremely important that these inflators be visually located before any extrication procedures begin. Unlike the solid propellant gas canister built into the passenger's frontal airbag, these inflators have no protection around them; they are simply a long thin tube that is filled with a compressed inert gas.

Some vehicles, such as the Volvo XC90, Infinity QSX, Nissan Pathfinder, Armada and Quest mini-van, and Ford Excursion have head curtains in two sections, requiring two cylinders to deploy the curtain. Again, it becomes extremely important to expose as much of the plastic as possible prior to beginning any evolutions.

3. Side impact air bags

Side impact air bags are designed to protect a passenger's head and thorax with some style of bags or just the thorax with another type of bag. Some of these bags are designed to help keep an occupant from being ejected from a vehicle in a roll over. Like the frontal airbags; side impact airbags must have a crash sensor to recognize that a crash has occurred. These sensors are usually mounted in the frond door, the B post, or most are located inside the rocker panel just below the B post. The cylinders for these bags can be mounted in the B post and also underneath the folded air bag in the seat back. Some older vehicles used the same chemical propellant, sodium azide, used in frontal air bags.

The air bags can be mounted in one of two locations: the door or the out board side of the seat back. The door mounted bags can either mounted on the inside of the door and deploy from a blow out panel.

Some newer door mounted bags pop up, like a toaster, from the top of the door. The 2010 Volvo C70 convertible has an air bag that extends the entire length of the passenger compartment, from the A post to the rear of the passenger compartment. This bag is extremely rigid so that it can provide the necessary head protection, even without a roof. These bags obviously present a danger to rescuers who are leaning over the door of a car that has not had the battery disconnected.

Side impact bags that are mounted in the seat are usually powered by high pressure cylinders. Some older cars, however, still use chemical propellants. As stated before the cylinders can be mounted in the B posts of the vehicle or in that actual seat back itself, usually under the folded air bag. The seat mounted bag is usually placed under the seat fabric in the out board side of the seat. It can either come out of a blow out panel or from a pre stressed seam in the fabric that is designed to tear open on air bag deployment.

The picture on the left is of a head/thorax bag, the right is a thorax only bag.

The danger with this type of air bag is its deployment path. The normal path is to first deploy outwards before it goes forward. The bag uses the closed door to rebound inward changing the direction of the bag. If a door is opened or has been removed, a rescuer standing in the door way may think that he is out of the deployment zone, but due to the bags deployment path, might be placing him or herself in danger.

This picture illustrates this deployment path well:

*If the seat back is going to be cut and removed, it may be a good idea to cut through the fabric to locate the cylinder in the seat back (if it is in the seat). This will ensure that our cutting tools will not cut through the cylinder.

Side impact air bags and head curtain or tubes are tied into a vehicle's Roll Over Protection System (ROPS) which will be discussed later in the chapter.

4. Occupant Positioning Air Bags

Occupant positioning air bags are different bags placed throughout the vehicle that work together, along with the seat belt and pretensioner, and have the sole purpose of keeping front seat occupants from sliding out of the seat in a front end collision. In this type of collision, a person in the front seat usually slides out of their seat and is thrown under the dash if this system is not in place. This is known as "submarine" and usually meant significant injury or death to the occupant. Some vehicles may have some or all of these types of bags and some vehicles may not be equipped with any at all. All of these bags present their own unique dangers that we will now discuss.

Knee bags or bolsters

These bags deploy exactly where their name suggests. They are usually placed under the steering column and under the passenger side dash board. They function not only as part of the Occupant Positioning System, they also reduce the severe knee and hip injuries that normally occur during a front end collision. These bags, as well as the others we will discuss, work in conjunction to keep the occupant in their seat. There are two basic types of bags: the knee bag and the knee bolster. Both serve the same purpose.

The knee bag is just a simple air bag that deploys outward from the dash toward the front edge of the seat. These bags are usually powered by the same firing units and propellants (sodium-azide) as the frontal air bags and are usually identified on the blow out panel.

The picture below on the left shows an identification stamp. On the right is a picture of a deployed knee bag.

The knee bolster serves the same purpose as the knee bag but has slight design difference. This bag has a panel or bolster that is attached to the bag itself. When the bag is deployed, the entire bolster panel, with attached bag, comes out to make contact with the occupant's knees. The arrow in the next picture below clearly shows the bolster panel.

The same dangers inherent in frontal air bags are present with the knee bags and bolsters. Loaded knee bags or bolsters can cause significant injury if proper spacing and battery disconnection are not achieved. If these bags are present, rescuers should suspect that the following air bags are also present and take every precaution to stabilize the hazard, prior to extrication operations.

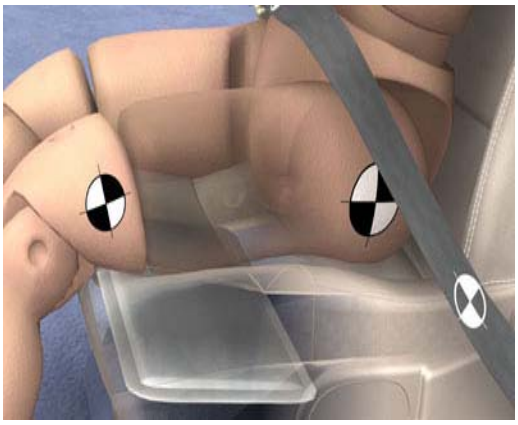
5. Carpet Bags

Carpet bags are mounted in the floor board of the vehicle and use the same sensors as frontal air bags. These air bags deploy using a pressurized gas cylinder that is usually mounted over the center tunnel. The purpose of this bag is to push the occupant's feet up, thereby slightly changing the angle of the occupant's legs. This slight change of angle in the legs will help keep the patient from sliding out of the seat and under the dash. The danger comes more from where the pressurized cylinder is mounted. Rescuers may not expect that cylinder is in the center tunnel and cut through it or weaken it during operations.

Picture of a deployed carpet bag

6. Anti-slide Seat bags

The anti-slide seat bag is one of newest bags to be installed in vehicles. It is not actually a bag, but instead a thin metal envelop structure that is mounted under the foam cushion of the seat. The operating principle of this bag is similar to an airbag except that the bag never comes in contact with the occupant. The bag operates in two stages upon receiving the firing signal from the ECU: First, a gas generator inflates the metallic envelope which pushes the foam up in the front edge of the seat. This action pushes the occupant back and against the seat back. Second, a deflation controller beneath the module slowly deflates the envelope and causes the metal envelope to form to the shape of the pelvis. This forms a pocket in the seat to hold the occupant in position, forming a protective shield around the pelvis. It also assists the carpet bag in lifting the weight of the occupant's legs, preventing the downward force of the feet pushing into the floor.



With this bag, the obvious danger occurs when a rescuer places his or her knee on a seat with an un-deployed bag.

Miscellaneous Air Bags

In this section we will illustrate what the rescuer has in store for him as far as the future of the air bag. The direction of seat belt technology shows us that the possibility of air bags and their locations is limitless.

This air bag is in the head rest of the **rear** seat in a passenger car.

Here we se an air bag installed in the seat belt.

Not all air bags will be inside the patient compartment. Soon, rescuers will be faced with hood, front bumper and/or windshield air bags.

The Jaguar XK has 2 airbags under the hood that help to protect pedestrians by cushioning the hood and decreasing the impact force into the windshield.

Ford will soon be unveiling a bumper and windshield air bag that is designed to protect the pedestrian from impacting the bumper and hood. The windshield bag will decrease the force of impact with the windshield while assisting in vaulting the patient over the windshield and roof of the car.

Air bags will not only be seen in cars, they will also be installed on motorcycles as well. This air bag is designed to deflect the path of the rider up and over the impacted vehicle. Before, the rider would fly directly into the vehicle causing fatal head and neck injuries.

An airbag vest is available to motorcycle riders to give protection to the head and upper torso in a crash. The vest is only effective if the rider is wearing a helmet.

As we have clearly seen, air bags present a very real danger to both rescuers and patients during extrication operations, regardless if they have deployed. The most important thing to take away from this is to always operate as if you are surrounded by live and loaded air bags. Vehicle manufacturers have installed safety devices in an attempt to prevent accidental deployment but we should not and can not depend on those devices to be operational after an accident. **Even if the vehicle has been stabilized and the battery has been disconnected, you must protect yourself, your crew and your patient from the possibility of being impacted by an air bag.**

How Do Air Bags Work?

The typical auto accident lasts approximately an eighth (.125) of a second. Within this time frame, the ECU must determine that an accident is about to occur, designate the appropriate safety systems to activate and deploy those systems to create a protective cushion between the occupant and the vehicle's' interior.

Frontal Airbags:

Specifically designed for a frontal impact, these airbags will only deploy in a front end type of collision. The vehicle must be impacted either straight on, or within a 30 degree angle from either side of the center line of the vehicle.

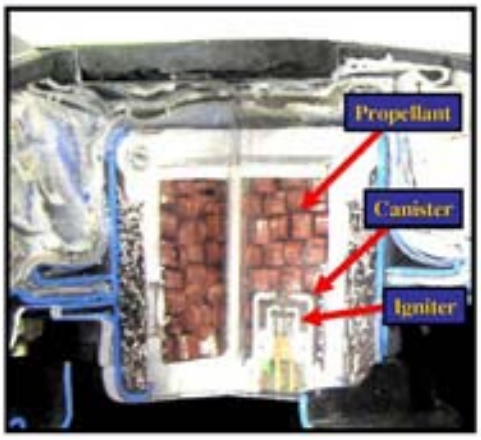
The first step in deploying an airbag is for the system to realize that a crash has occurred. This is accomplished through information gathered by crash sensors. There are different types of sensors; the earlier less complex ones were simply mounted near the bottom of the radiator support, at the front of the vehicle and worked on the basis of compression of the sensors. This area is respectfully known as the crash zone. The more complex sensors, called Micro- Machined Accelerometers are mounted inside the control module, or airbag brain itself. These actually measure the speed and severity of the crash.

To understand how these work, you must first understand what is meant by deceleration. The sudden slowing of the car from a collision is called deceleration. If your car is going 30 mph, your body is also going 30 mph. If the car hits a wall and suddenly stops your body not being a part of the car is

still traveling at 30 mph, causing you to lunge forward. These sensors work on the same principle; the sensor housing being part of the car, stops at the same time as the car but the internal parts (like your body) are still moving at 30 mph, causing them to lunge forward and contact an electrical switch completing the circuit. This electrical impulse is then sent to a control module, or airbag brain. The control module is simply a small computer that receives impulses from many sensors, sorts them out, decides which airbags to deploy, and sends an impulse to the appropriate destinations for deployment.

To prevent airbag deployment in small fender benders, the control module can not deploy an airbag by receiving only one signal. Every control module must receive two or more impulses to deploy an airbag. This second impulse comes from the safety or arming sensor. This sensor is usually mounted inside the vehicle and must also experience a sudden deceleration just like the crash sensor.

Once the control module determines that we do have a true crash, it will send an impulse to the inflator squib, or igniter. This igniter is an electrical unit that has a tiny bridge wire, much like you see inside a car fuse. As the electrical current travels through this wire, the extreme resistance causes it to over heat, igniting the airbag's Sodium Azide propellant.



Sodium Azide, the same type of fuel used to send rockets into space, is a rapidly burning fuel that puts off extreme amounts of nitrogen gas and heat. This nitrogen is then passed through filters and fills the nylon airbag. Depending on the manufacturer, these airbags will deploy between 200-300 mph. The time the car crashes to the time the bag is completely full is approximately 15 milliseconds, less time than it takes to blink your eyes. This allows the bag to be completely filled before the occupant's body is thrown forward. As the occupant falls into the bag; the nitrogen has already begun to escape through vent holes in the bag, slowing the occupant's momentum. At the same time, the shape of the bag is distributing the occupant's weight over a wider area, softening or cushioning the occupant's impact.

Side impact airbags/head curtain air bags:

Like frontal airbags, side impact airbags must be impacted from a certain angle. The left side airbags will not deploy if the vehicle is impacted on the right side and vice versa. These air bags use crash sensors that are similar to those used for frontal airbags. These sensors are mounted below or near the B post, or center post, between the doors, and are independent of the frontal airbags. In a side impact the frontal airbags will not deploy. However, in newer vehicles, these air bags are tied into a vehicle's Roll-Over Protection System (ROPS) and will deploy if sensors in the vehicle determine that a roll over is imminent.

Roll-Over Protection Systems (ROPS)

A ROPS is a term that is commonly refers to the roll bars in convertible cars that deploy in a roll over, but these systems can also be present in non convertible cars. It is actually a system that consists of sensors, side and head curtain bags, seat belt pretensioners *and* roll bars. The purpose of this system in a non convertible is to protect the occupant from being ejected during a rollover.

To begin, the roll sensors in a ROPS are much more complex than a crash sensor in a non ROPS vehicle. In a vehicle equipped with a ROPS, there are two main sensors that send vital information to the ECU. The first is an electronic roll over sensor that measures if a vehicle is tilting and how fast the vehicle's lean angle is changing. These measurements are being fed to the ECU which is constantly monitoring the possibility of a roll over. The other sensor, an inclinometer, measures the lateral and vertical acceleration, the vehicle speed and roll rate to predict the impending rollover. When the sensors detect a potential rollover, the control module triggers the curtain airbags, seat belt pretensioners and in convertibles, the roll bars.

This picture shows and electronic roll sensor mounted along the inside of the bottom of the rear post.

The ECU protects against accidental deployment by comparing the vehicle's tilt angle to the roll rate to determine whether the vehicle will roll or recover from the roll. If the vehicle is in fact going to roll, the ECU not only deploys the side impact and head curtain airbags, but matches the deployment speed of the bags to the severity of the rollover.

The curtain air bags, or "Safety Canopies", used in these systems are similar to curtain bags in a non ROPS vehicle, but have a lot of characteristics that make it quite unique. Like other curtain air bags, older Safety Canopies protect from the A to C post while newer curtains extend all the way to the third row. Also, like regular head curtain bags, they are hidden in the head liner along the roof rails.

The differences between the two are the design and storage of the bags, their deployment and the method in which they protect the occupant. The bag itself is different than most airbags in that most airbags depend on thermal expansion for volume. In a normal system, upon receiving a firing signal the gas created by the sodium-azide explosion is an extremely hot gas. This heated gas is what expands and fills the bag. The gas within the bag cools and begins to escape through the porous material of the bag, the bag then loses volume rapidly, causing it to deflate. The Safety Canopy airbag uses a cool-gas inflator and low-porous bag material. The combination of the cool gas and the low porous bag means that the air bag retains its volume much longer, allowing them to remain

inflated for up to 6 seconds, or approximately the time it takes an average vehicle to roll over a few times. These airbags have a controlled deployment speed and may deploy much faster than other airbags.

The next difference is the method in which the Safety Canopy is folded and stored. The bag is about 5 inches thick and the deployment zone is from the roof rail to the bottom of the window, the full length of the vehicle. These bags are stored using the "Roll Fold Technique", which means that they are folded in a way that makes the bag roll down between the window glass and the occupant, rather than expanding like an accordion. This rolling affect allows these curtains to deploy even if the occupant is out of position. The bag will actually roll between the occupant's head and the glass, which pushes the seat occupant upright into the seat.

The next difference is how the Safety Canopy protects the occupant from ejection, which is not only how it deploys, but also in how it is attached to the vehicle. Once these bags deploy, tethers located on the bottom corners of the bag, lock them in place to prevent occupants from being ejected. The "Safety Canopy" also acts as a regular head curtain airbag in the event of a side impact collision. The control module will override the rollover sensor and allow the igniter to deploy the canopy in the same manner as a head curtain airbag.

The arrows in the picture below show how the bag is tethered.

*These bags, as well as all curtain air bags, are single stage bags so they will only deploy once. If the bag has deployed, it will be safe to cut the bag and tethers to gain access to the patient. These airbags, like all curtain bags, are large and deploy straight down to the bottom of the window. They are capable of deploying with enough force to cause severe neck injury if a rescuer is leaning into a window. Also, rescuers need to be aware of the possibility of having a second, un-deployed curtain that extends all the way back to the third row. The presence of this second curtain means that there will be a second loaded pressurized cylinder.

ROPS bars in convertibles

There are two types of ROPS bars in convertibles: the fixed or static bar and the deployable or dynamic bar. The purpose of these bars is to protect the driver and all passengers in a convertible during a vehicle rollover. The fixed bar is a very simple yet effective design. It remains fixed in place and presents little to no danger to rescue workers.

The deployable type, on the other hand, is significantly more complex and dangerous. There are two types of deployable roll bars: the bar and the hoop. The bar is hinged on both sides of the vehicle and can be deployed either hydraulically or by using a spring and latch mechanism. Once activated, the bar flips up from a hidden compartment behind the rear most seats to protect the passenger's heads. The other type is the hoop. The hoops are placed behind the seats and pop up above the seat head rest. The hoops are also deployed either hydraulically or by using a spring and actuator latch device. Both types become locked in place, once they deploy.

The danger with theses types of systems is that they are placed in the exact location where most rescuers would place themselves to begin treatment of the patient. If the bar or hoops have not deployed, the tendency for rescuers is to reach across the back of the vehicle to hold C-spine or begin treatment. This puts us right over the deployment zone. ROPS bars or hoops are designed to deploy within three tenths of a second, so the amount of force generated in order to accomplish this is enough to cause a serious injury or fatality. Some of these systems may be easily identified; others may not be so obvious.

In order for these systems to activate they must receive information from different sensors. One sensor is an inclinometer that senses the vehicle inclination and lateral acceleration, or how fast the vehicle is tilting. The other sensor is a G-sensor or gravity sensor that senses the vehicle weightlessness if it becomes airborne. For the system to deploy, one or any combination of the following must occur:

1. The vehicle approaches a lateral angle limit of 62 degrees

2. The vehicle experiences a later acceleration of 3 Gs

3. The vehicle approaches its longitudinal angle limit of 72 degrees.

4. A combination of longitudinal acceleration and longitudinal angle would cause the vehicle to roll in a forward or end over end direction.

5. When the vehicle's G sensors sense vehicle weightlessness for more than 80 milliseconds.

Some systems, such as those in Mercedes convertibles, have a manual deployment switch mounted on the dash. If the batteries on these vehicles can not be secured, rescuers can manually deploy the bars if necessary. The manual deployment is much slower than a normal deployment and will render the bars safe.

Seat Belt Pretensioners

History

Mechanical seatbelt pretensioners came into play at the same time full three-point anchoring systems were employed. Some means were required to prevent excessive seatbelt slack with systems using non-fixed belt lengths. Excessive seatbelt travel allows too much occupant motion during a crash, thus increasing the chance of contact with components such as the steering wheel, dashboard or windshield. Too much occupant travel also means that in a crash, the speed the occupant is traveling in the vehicle is extremely high compared to the speed of the vehicle as it makes contact with the other object. This also means that significant impact energies are developed by the occupant when contact with the interior of the vehicle is made. In the end, this translates into increased potential for injury in an accident.

There are essentially three types of pretensioners: mechanical, electric and pyrotechnic

Mechanical

Mechanical pretensioners use an inertial wheel with a pendulum and ratchet device that moves under the rapid deceleration of the crash to lock the belt into place. These mechanisms can often be detected by giving a sudden tug on the belt. The pendulum and ratchet interact in such a way as to lock the reel and therefore the belt into place during an accident, preventing any further travel of the seatbelt and occupant. These devices would more accurately be called limiting devices rather than pretensioners, as no true pretension is imposed within the belt itself.

Electrical

Electrical pretensioners replace the mechanical means of sensing deceleration (the pendulum) with an electrical device that may or may not be tied into the airbag ignition circuits.

Pyrotechnic

It became apparent that more occupant protection could be accomplished if some tension could be developed in the belt. The use of pyrotechnics in automotive airbags helped forge the way for use of pyrotechnics in seatbelt pretensioners. These devices use small pyrotechnic charges to pull the

seatbelts into place and actually generate tension in the belt during a crash. This keeps the occupant travel to a minimum and also helps optimize occupant position for effective use of the airbag systems.

Operation

Pyrotechnic seatbelt pretensioners operate on either the buckle or the ratchet side of the seatbelt mechanism. Their action augments or compensates for a variety of seatbelt performance issues, including:

- Taking up any slack in the belt prior to occupant moving forward during a crash
- Compensating for the “film spool effect” of the seatbelt webbing unwinding upon itself on the locked ratchet.
- Holds the occupant in position for airbag contact and preventing the “submarining” of a front seat passenger in a front end collision.

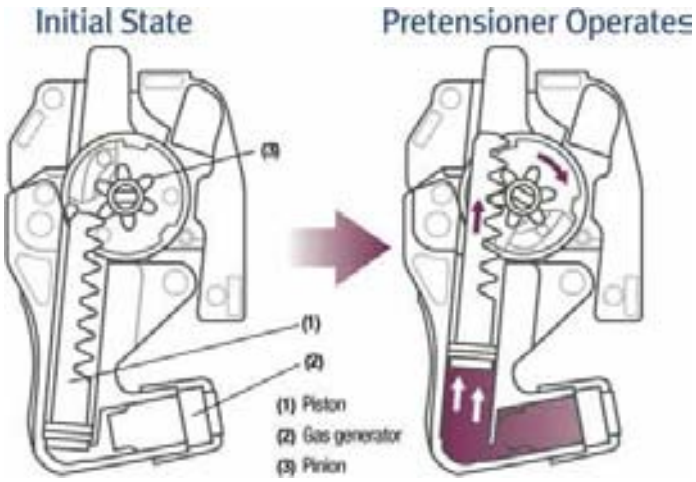
These features help optimize the performance of the airbag systems.

Maintaining proper occupant position reduces the amount of work the airbag must perform on the occupant, thereby increasing the level of protection provided by the airbag system. Keeping the occupant in the proper position also helps minimize injury due to the rapid inflation of the airbags.

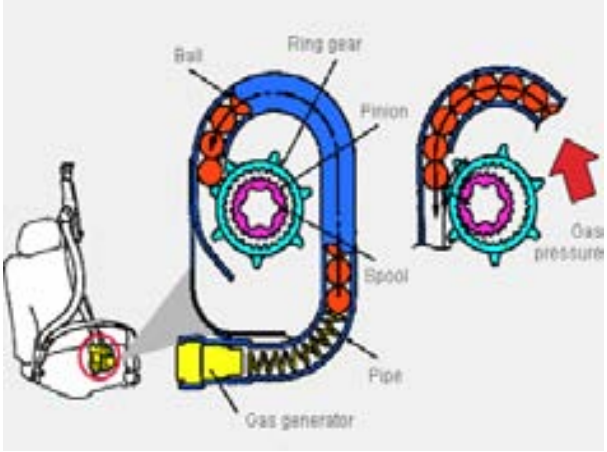
Pyrotechnic pretensioners are electrically triggered at approximately the same time as the airbags. Mechanical triggering can also be employed meaning that a hard, sudden tug on the belt can lock it temporarily. The combustion of the pyrotechnics within the pretensioner creates pressure that is used to either pull on the ratchet side of the seatbelt mechanism or to tighten up on the spool side of the mechanism, thus reeling in some length of the seatbelt webbing. Some means of mechanical locking is usually employed to maintain belt tightness.

Here are two different types of belt or spool side pretensioners.

Here this illustration shows the basic operation of one type of belt side retractor. As the gas generator (2) receives its firing impulse, it releases the gas to shoot the piston (1) up. As the piston moves up, the teeth on the piston catch the teeth of the pinion (3), causing it to pull the slack out of the belt.

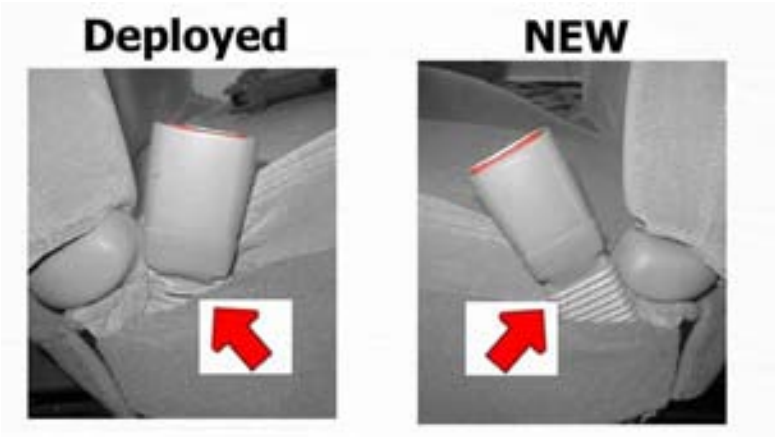


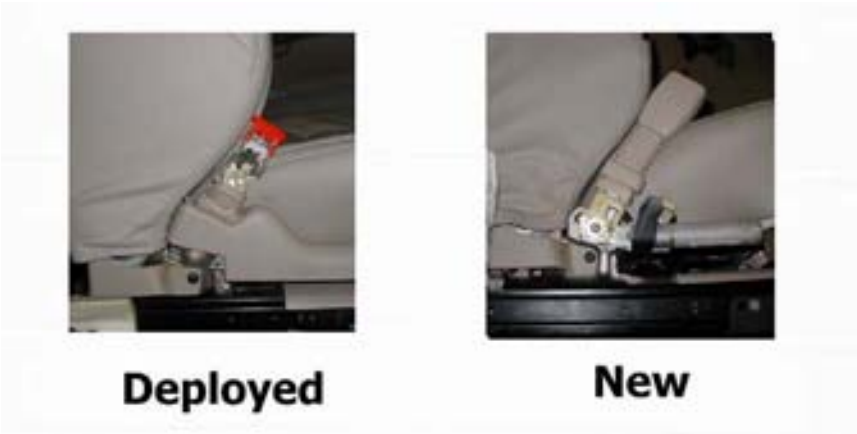
The next type of belt or spool side pretensioner can be extremely dangerous to rescuers and patients. They could be mounted on the lower portion of the B post or on the posts for the rear seats. This type uses steel balls, sometimes the size of marbles, to engage and turn the pinion. As the illustration shows, once the gas generator receives the firing impulse, the balls are forced through a small pipe. These balls then engage the pinion teeth, which turns the spool and tightens the belt. The danger occurs during cutting operations. If this pretensioner is cut, these steel balls can now become high speed projectiles. It is extremely important that we stay away from these mechanisms during extrication operations.



The other type of pyrotechnic pretensioner is the ratchet or buckle side pretensioner. This pretensioner retracts at the portion where the belt buckles, the ratchet. This type of pretensioner typically uses a smaller stored gas cylinder that pulls the buckle down to take the slack out of the belt. The danger present in these pretensioners is the stored gas cylinder. The same precautions that are taken with air bag cylinders must be taken with these pressurized cylinders; they are not to be cut with anything, they will become high speed projectiles. Below are pictures of the buckle or ratchet side pretensioner.

When a pretensioner has deployed, typically there is visible evidence. If the belt or spool side pretensioner has deployed, usually the belt will no longer retract or conversely it will no longer be able to be pulled out, it will be extremely tight. If a ratchet type pretensioner has deployed, typically there is evidence of a contracted buckle or obvious damage to the receiver itself. The pictures show what different pretensioners look like before and after deployment:





As previously stated, the safety systems installed into today's modern vehicles have made it possible for drivers and passengers to walk away from severe auto accidents with little to no injury. These systems are continually improving to make auto safety more effective. This same innovation, however, can make operations more difficult and dangerous for rescuers and patients during extrication. We have learned that auto manufacturers must adhere to safety standards that are only becoming more stringent. We have also learned that even with these tougher standards, there is still nothing in place that mandates a common mounting location for the high pressure cylinders needed for airbags. Never before has it been so important to know how to identify and mitigate these systems.

The knowledge gained so far must be used constantly in an effort to make operations safer and more efficient. The hazards identified in this chapter make it a necessity for rescuers to constantly train and familiarize themselves with these new systems. With the development of new airbags, the 5 – 10 – 20 rule is only good as a general rule that covers a portion of the possible bags in a vehicle. As rescuers, we must operate on the assumption that all airbags, even deployed airbags, are dangerous and must protect ourselves in a manner that reflect that assumption. If we are unable to shut the safety system down by disconnecting the battery, the best way to protect ourselves is to stay out of the deployment zone. But in the end our best defense against the dangers that airbags pose, is knowledge. And the only way knowledge of these systems can be gained is through constant training and education.

ALTERNATIVE FUEL AND HYBRID VEHICLES

When alternative fuel vehicles are mentioned, the red flag warnings in all of our minds are raised. There are a lot of misconceptions out in the field regarding safety of these vehicles. But we must understand that alternative fuel vehicles are required to be as safe, if not safer, than vehicles using conventional fuels. There are safety devices installed at key areas of the vehicle that disable the system. However, because of the fact that the vehicle has been in a crash significant enough to require extrication, we should not rely on those safety systems and must protect ourselves and our patient as much as possible.

Alternative fuels are fuels that can replace ordinary gasoline and may have particularly desirable energy efficiency and pollution reduction features. There are many different fuels in use today such as: natural gas (CNG or LNG), propane (LPG), Hybrids, Ethanol (FFE or E-85), Electricity, Hydrogen, Biodiesel, Biogas and home do-it-yourself kits. All of these fuels have their own hazards but all can be dealt with a planned, systematic approach. In this section, we will cover the basic operation of these vehicles and more importantly, their hazards and the methods to stabilize these vehicles. The shut-off and stabilization procedures will be discussed in the Vehicle Stabilization section of the chapter.

Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Propane (LPG)

A CNG, LNG or LPG vehicle uses an internal combustion engine fueled by either of the three fuels. The vehicle may have a blue CNG label on the rear, a green NGV (Natural Gas Vehicle) label on the side of the vehicle for identification purposes. Some vehicles may have no identification label at all. Unfortunately, there aren't any regulations that require the marking of these vehicles. These vehicles are becoming more common on the roads today. Propane has been used as a commercial motor fuel for more than 80 years, and more than 190,000 propane-powered vehicles are in use today in the United States-more than 9 million are in use worldwide. Propane has become the leading alternative fuel in the United States and in the world.

The fuel tank used for these vehicles is pressurized to approximately 3600 psi. The storage cylinders can be made of steel, aluminum, or plastic. Lightweight composite cylinders are especially beneficial for vehicular use because they offer significant weight reductions when compared with earlier generation steel and aluminum cylinders. These vehicles are extremely safe during normal operations. Propane vehicle tanks are tested to four times the normal operating pressures, and the tanks are 20 times as puncture resistant as gasoline tanks. Propane is nontoxic, nonpoisonous, and has the lowest flammability range of any alternative fuel

In CNG vehicles, the high pressure fuel flows from the tank to the engine through a stainless steel fuel line under the vehicle. In LNG and LPG vehicles, as the engine runs, the liquid in the tank "boils-off' into a vapor state in the upper regions of the tank and continually replenishes the drawn-off vapor that is burned in the engine.

CNG is often confused with liquefied natural gas (LNG). While both are stored forms of natural gas, the key difference is that CNG is gas that is stored at high pressure, while LNG is compressed in liquid form to usually around 200 plus psi. CNG has a lower cost of production and storage compared to LNG as it does not require an expensive cooling process and cryogenic tanks. CNG requires a much larger volume to store the same mass of gasoline or petrol and the use of very high pressures (3000 to 4000 psi, or 205 to 275 bar).

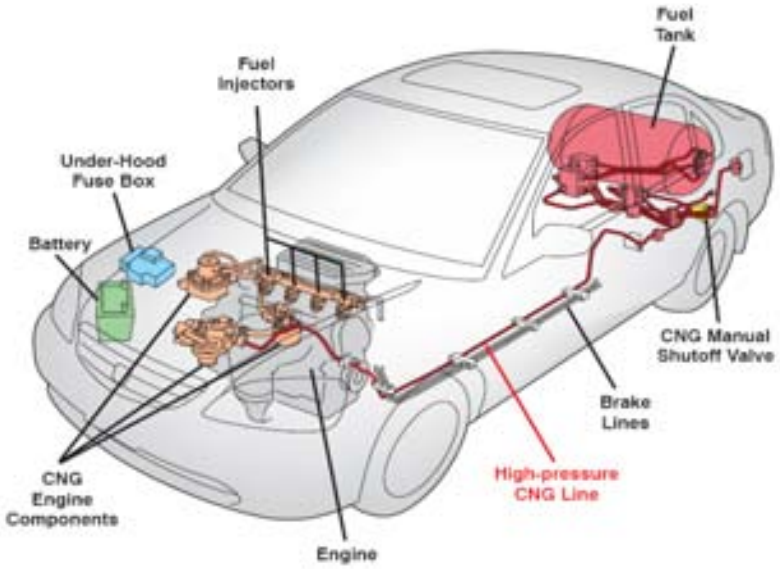
The following pictures show common mounting locations for these tanks:

The main hazard associated with all of these vehicles is the possibility of explosion if there is direct fire impingement on the storage vessels. With either type of fuel, the potential for explosion is present, whether through BLEVE in LPG and LNG or increasing vapor pressure of CNG vessels. These gases have flammable and explosive ranges much greater than that of ordinary gasoline and as such, are much more dangerous if released from their containers. Natural gas is lighter than air, so it will rise and dissipate quickly. Propane, however is heavier and will sink and hug the ground in search of an ignition source. If the vehicle is on fire, there is an added aspect of danger that must be dealt with prior to extrication.

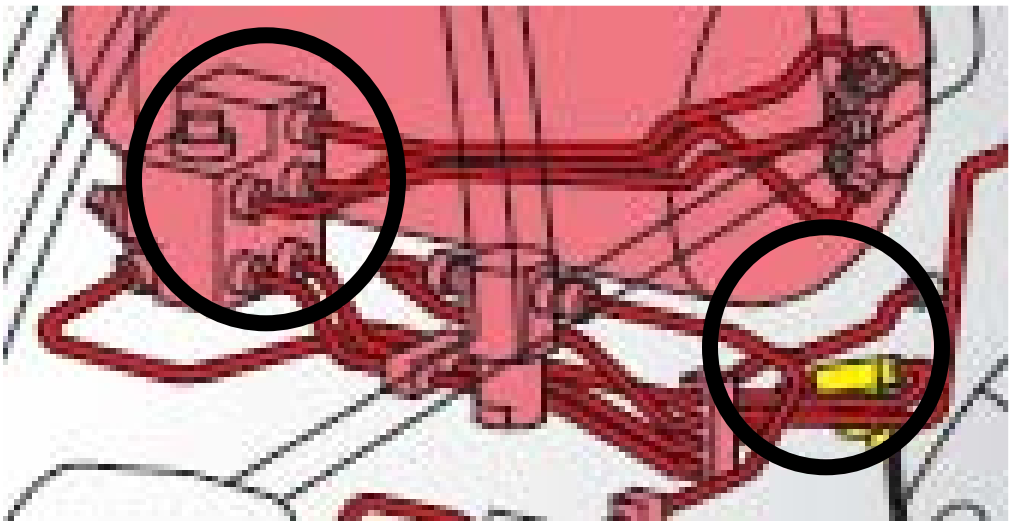
There are safety mechanisms and manual shut-off valves are placed throughout the vehicle to increase safety. There are always two shut-off valves on a CNG vehicle. One is located in the high pressure

system, usually close to the tank, that automatically shuts off the flow of gas whenever the ignition key is turned off, the battery is disconnected, or a leak in the system is detected. The second is a manual cut-off valve which is typically located near the rear tire. There is, however, a small amount of residual fuel left in the fuel lines, even after these shut-off valves are closed.

The pictures below shows a typical set up of a compressed natural gas vehicle and its shut-off locations:



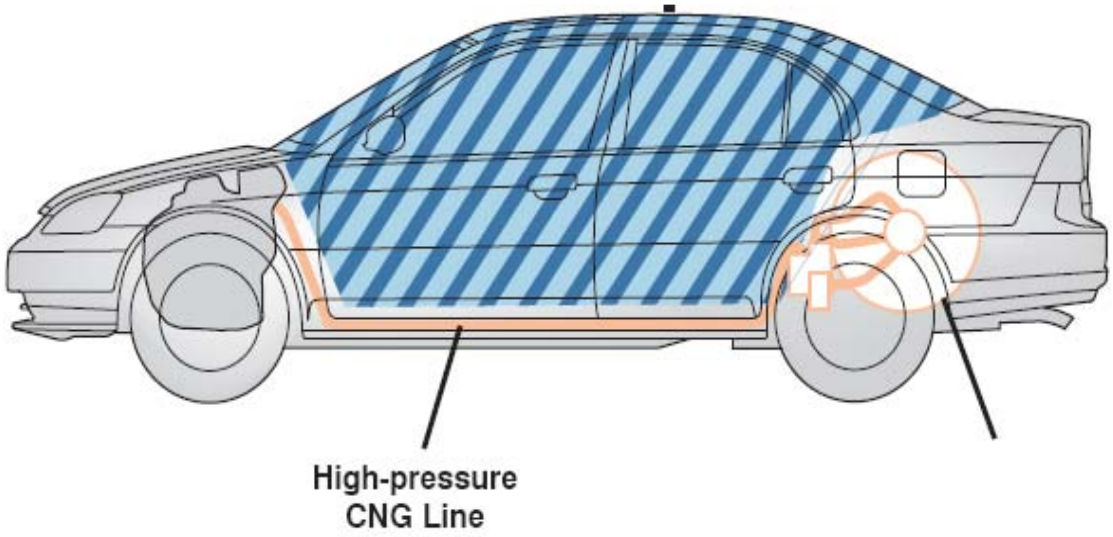
The handle on the valve is red and cuts off the flow of CNG from the tank. The circles show the shut off valves.



Another safety feature for these vehicles is the pressure release valve located on all of the tanks. The valves name states its intended purpose and performs the same function as those found on any other high pressure vessel. If the pressure in the tank increases to a certain point, the valve opens and releases the tank's contents until the pressure in the vessel is reduced to a safe pressure. This commonly occurs when there is flame impingement on the vessel itself. If this occurs, rescuers will hear a loud intermittent hissing sound coming from the vehicle.

Unfortunately, as is common in the auto industry, there is no common mounting location for these valves. If there is fire present, the vent can be releasing pressure in any direction: right, left, up or down. Again, the fire and the increasing possibility of tank failure must be dealt with prior to commencing extrication operations.

The blue shaded area in this next picture shows the safe cut zone in these types of vehicles. The circled area shows the location of the manual shut-off valve.



Hybrids

There are many types of Hybrid vehicles available with new designs being continuously developed. The key to Hybrid efficiency is the battery. As new battery technology is developed, new hybrid designs will become available. Hybrid technology is increasing at an unbelievable rate. Passenger vehicles are not the only vehicles that are hybrids. The greatest benefit of Hybrid technology will be seen in the Medium and Heavy Truck industry. The hybrid will allow the operator to rest with full use of all of his electronics and comfort features like TV and AC without the engine running. It will also give the greatest benefit in fuel savings.

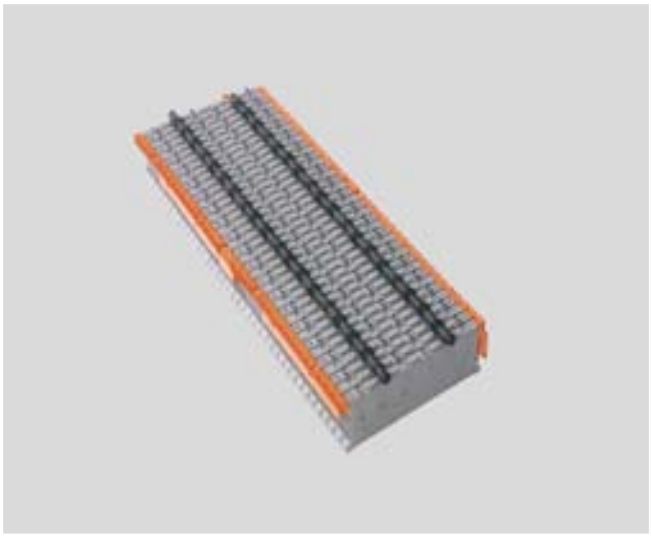
Eventually Hybrid trucks will have the technology to automatically shut down the diesel engine and run on electricity only while traveling through areas with high air pollution. This Hybrid system is contained within the transmission assembly. There is a high voltage battery pack on the side of the truck that supplies power to the transmission to drive the vehicle and the transmission also operates as a generator to recharge the batteries.

Regardless of the type or brand of vehicle, their basic operating principle is the same; a gas or diesel engine is used in conjunction with an electric motor that is powered by a high voltage battery pack. A computer in the vehicle determines which engine will be used, which is usually dependant on the driving conditions. The high voltage battery pack is recharged during driving, usually when the brakes are applied.

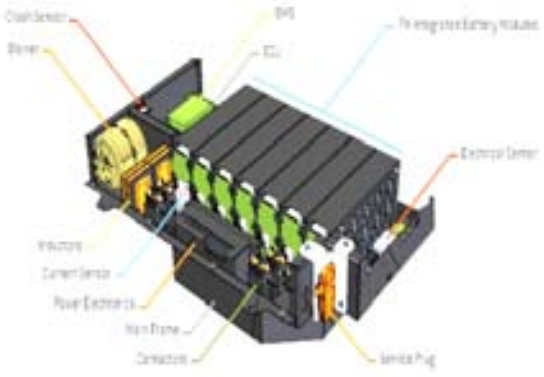
The batteries in these vehicles have evolved since the early days of the Electric Vehicles. Today Nickel-Metal-Hydride (NiMH) is being used for hybrid batteries instead of lead acid to reduce the weight and deliver more energy from a smaller package. Because a hybrid also uses a gas engine, the size of the battery is not as large as a pure electric vehicle EV battery. On vehicles such as the Honda Civic and Insight, and the Toyota Prius, the hybrid battery voltages are 300 volts or greater.

Lithium Ion batteries have now been developed that are safe for use in an automobile. These new batteries contain internal fuses that shut down the high voltage if the battery is overheated or the electrical system is shorted. A major drawback to Lithium Ion batteries at this point is that these batteries are still very expensive.

Typical Nickel-Metal-Hydride battery:



Lithium Ion battery



As the hybrid's computer, which is run by the car's 12 volt battery, decides that the vehicle will run on the electric motor, a relay on the high voltage battery pack closes and allows the electrical current to travel through the infamous orange cable to the an inverter. The inverter then converts the DC power to AC which then powers the electric motor. Again, as the brakes are applied, the high voltage batteries are recharged.

Since the inception of the hybrid vehicle, rescuers have been concerned with the hazards associated with the battery pack in hybrids. There are a few misconceptions regarding these vehicles during extrication operations. The first concern is regarding the condition of the battery pack itself after an accident has occurred. But the main one is about the possibility of electrocution when cutting through the high voltage cables coming from the battery pack. Vehicle manufactures understand the hazards associated with these batteries and have constructed them to be extremely safe. These vehicles, as well as the other types of alternative fuel vehicles, can be considered as safe, if not safer, than conventionally powered vehicles.

To address the first concern, the battery packs are encased in a container that is essentially bomb proof. Very rarely will a case break and expose the high voltage batteries. It would take an extremely severe crash to break into the protective casing of the battery pack. There is more of a hazard from

leaking battery acid than there from the possibility of electrocution. As for the orange high voltage cables that run from the battery pack to the motor, there are a few safety devices in place, as well as shutoff procedures that can be done by rescuers that will render the vehicle safe for operations. As stated before, every hybrid battery pack is equipped with relays that must be closed in order for current to flow through the cables during normal driving operations. If these relays are open, the circuit is broken and the current can not flow. There are several circumstances in which these relays will open. The first and most simple way is when the vehicle is shut off at the ignition. This simple action opens the relay and does not allow any current to flow through the cables. Another way is if the computer senses a short anywhere in the system. A short can occur if the cables have been cut, either during the accident or by extrication operations. If there is even one small wire protruding through the cable sheathing, the computer will sense the short and open the relay. Another way the relay opens is if any of the airbags deploy. As soon as the computer senses the deployment, the relay opens.

The safety disconnects will also open the relay. However, the safety disconnect is not designed as an emergency device for rescue workers. It should not be considered during the rescue. It is normally used to disable the system for service purposes. Prior to moving the vehicle after all patients are extricated, the safety disconnect should be pulled, usually by the tower. This is a safety measure to ensure that nobody is accidentally injured by connecting the battery or turning on the ignition switch. The vehicle must also be towed on a flat bed truck or with the drive wheels off the ground because some vehicles recharge their batteries when the gas pedal is released and the vehicle is coasting.

The following pictures show some safety disconnects in different vehicles:

The last way to open the relay is to disconnect the 12 volt battery. For emergency personnel, this is the only way, which also happens to be the most effective method, of securing the high voltage battery pack. First, if possible, the transmission should be placed in park, then turn the ignition in the “off” position and then disconnect the 12 volt battery. This procedure will effectively stabilize the vehicle, the high voltage batteries and cables, and the vehicle’s passenger safety systems. Once this has been performed, the hybrid is, for all intents and purposes, a conventional car and safe for extrication.

By no means are we saying that cutting through the orange cables is safe after these procedures are performed. They should still be considered dangerous and we must always protect ourselves and our patients. One reason for this is that all hybrids are equipped with capacitors that store and release energy as needed. These capacitors continue to hold a high voltage charge for up to 10 minutes after the battery is disconnected, ignition is turned off or the safety disconnect is removed. Care must be taken not to drive any objects into the capacitors while charged. These capacitors will also begin to discharge if the airbags deploy in the crash or the impact sensor senses an impact of sufficient force. The capacitors are located under the hood in the very front left corner directly behind the headlight.

The vehicles discussed in this section are the most common non conventional vehicles on the road. Each of them presents their own hazards that firefighters must deal with prior to beginning any extrication operations. Emergency crews must first identify these vehicles as alternative fuel or hybrid vehicles in order to mitigate these hazards. As with every vehicle, certain procedures must be completed to render the vehicle safe. Regardless of the type or brand of the vehicle, the same procedure can be used to help with the primary stabilization of the vehicle. These stabilization procedures will be discussed later in the stabilization section of this chapter.

EVOLUTIONS

Every extrication incident provides unique challenges to emergency personnel. No two vehicles react the same when involved in a crash, even if the crashes are similar. As rescuers, we must always take the approach that even though we may use the same evolutions from one vehicle to the next, we might have to choose different techniques to complete those evolutions. For example, one firefighter may prefer to attack a door from the hinge side and tend to train on this technique only. However, this same firefighter may be faced with a vehicle that does not allow access to the hinge and must then attack the door on the Nader pin side. Because of this possibility, all rescuers must become proficient in all techniques of extrication. This is necessary so that emergency crews can be as prepared and as confident as possible when approaching a scene requiring extrication. Knowing multiple techniques will also give emergency crews back up plans in case their initial plan of action is unsuccessful. This will ultimately make the scene safer for both the patient and emergency personnel.

As stated previously, the auto industry is using more exotic metals to provide a stronger, safer vehicle for its passengers. The use of these metals will test the limits of any and all extrication tools. Some hydraulic tools will not be able to cut or spread these metals. Extrication crews need to understand the limitations of their tools and work around these limitations. New techniques with different tools may have to be developed, sometimes on the scene of the incident. There may be a situation where the only option for patient rescue is to cut the car apart, in small pieces, from around the patient. These situations tend to be extremely time consuming, exhausting and stressful for all involved in the extrication.

When looking at these evolutions, it is important to remember that they represent the basic evolutions. They do not represent the entire spectrum of extrication techniques. There will always be a department somewhere in the country that has developed new methods of attacking vehicles. As crews become more proficient in extrication, more techniques can and should be developed.

The subjects covered in this portion of the chapter are: Common tools used for extrication, vehicle stabilization techniques, the “Golden Rules” of extrication, helpful techniques to use when attacking a vehicle, different methods of gaining purchase points, and step by step instructions on various extrication evolutions.

The following evolutions will be illustrated:
- Creating purchase points with hand tools and extrication equipment
- Door removal from both the hinge and Nadir pin side
- Creating a third door
- Roof flap/roll
- Roof removal
- Roof removal with a vehicle on its roof
- Roof removal with a vehicle on its side
- Dash roll
- Dash lift/spread
- Dash displacement with car on its side
- Side out on a four door vehicle
- Blow out on a four door vehicle
- Floor flap
- Tunneling
- Basic airbag ops
- Basics winch ops
- School bus anatomy and extrication techniques

THE TOOLS OF EXTRICATION

Just as any other firefighting equipment, extrication tools have come along way since their beginning. The first hydraulic tools were extremely heavy and awkward to work with. Today's tools are a lot lighter, more ergonomically designed and much more powerful. There are many different types of tools from many different manufacturers, some more limited than others. Here they will be broken down into different categories with a brief description given of each tool. By no means are the tools illustrated in this section the only tools that can be used, they are however, the most common. Which ever tools a department decides to carry, constant training is a necessity in order to become proficient in their use.

Hand tools

There are many different types of hand tools that can be used for extrication operations. These are the tools commonly found on all trucks that can also be used for extrication. From left to right: FUBAR, 8 lb sledge hammer, Haligan tool, flat head axe, bolt cutters and pike pole.

FUBAR
This tool is useful for a few different purposes including: breaking windows, prying and peeling the plastic to expose the posts. They can be found at any hardware store in different sizes for anywhere from $30 to $70.

Sledge hammer
This is a good striking tool that can be used along with the Haligan tool to create a purchase point. The most common size used is the 8 pound sledge.

Haligan tool
The Haligan can be used for prying and breaking glass.

Bolt cutters
Can be used to secure the batteries

Pike pole
Can be used in certain evolutions such as the Roof Flap to help fold back the roof

Stabilization Equipment

This equipment consists of different pieces used to stabilize the vehicle and create a solid working platform.

Cribbing, Step Cribbing and wheel chocks

Cribbing and wedges are very simple and consist of multiple pieces of 4 X 4 pieces of wood cut into different lengths. The cribbing is stacked up until they come into contact with whatever needs to be stabilized in order to keep it from moving or collapsing. They are commonly used in conjunction with other pieces of extrication equipment or lifting tools such as airbags or jacks. Step cribbing is cribbing formed with steps on the contact surface of the cribbing. They are quick to use and can simply be slid under the vehicle to stabilize. Step cribbing can also be used as wedges by turning them up side down and sliding them under the object to be stabilized. They can be manufactured using composite materials or by simply nailing pieces of 2 X 4 wood together to form the step cribbing.

Other types of step cribbing

Longer pieces of 4 X 4 cribbing and wedges can also be used for the stabilization process, as pictured below. On the left, a 10 ft section of 4 X 4 is being used to add support to the roof of the vehicle underneath. The middle and right pictures are showing how a vehicle on its side can be stabilized using a 4 X 4 cut down to the necessary length.

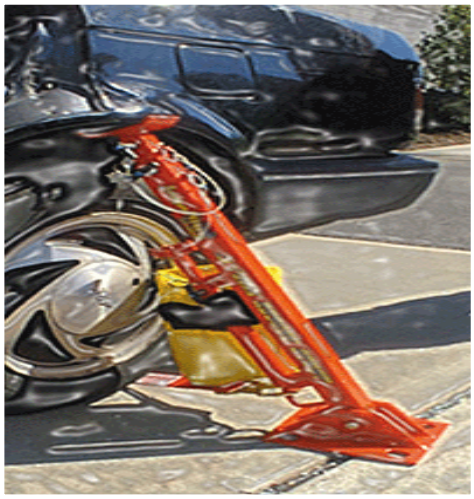


Wheel chocks are placed in front and behind a vehicle's wheels to prevent the vehicle from rolling. They can also be used as wedges by turning them up side down.

Struts

Struts are gaining popularity in the field due to their strength, versatility and ease of set up. They can be made of either steel or a composite material, depending on the manufacturer. Some struts are capable of lifting vehicles while some are used solely for stabilizing a vehicle that may be on it's roof, side or some other unstable position. Struts can support different weights, depending on their design and material used in the manufacturing process. Some expand by removing safety pins and simply sliding the sections out, others expand by screwing and unscrewing the sections while others are operated hydraulically or pneumatically. Each brand has its own accessories, again depending on the manufacturer.

Here are some different types of struts



Winch

A winch is a very useful tool that can be used to stabilize a vehicle. They come in different pulling strengths and use cables that can be made of a steel wire or a synthetic rope.

Hydraulic equipment

When we think of extrication, we think of our hydrauilic extrication equipment. These are certainly the pieces that garner the most recognition from the public and media. There are many different brands out on the market, each with it's own strengths and weaknesses, but they all run on one of two operating pressures, 5000 psi or 10,500 psi. The cutting, spreading, pushing and pulling forces of the

tools are generally the same. The difference with the two is the weight of the tools. In order for a 5000 psi system to generate the forces needed for extrication, the tools need to have a larger hydraulic cylinder diameter and piston or rod. This requires more material to manufacture the larger components which relates to heavier tools. In systems that run at 10,500 psi, the same forces can be accomplished with the use of smaller cylinders and rods, meaning lighter weight. Most makers of hydrualic extrication tools offer both low pressure (5000 psi) and high pressure (10,500 psi) systems. These systems can run on either hydraulic fluid or mineral oil, depending on the brand. The typical inventory of hydraulic tools includes spreaders, cutters and rams, however there are some specialty tools available.

Cutters

Cutters are very powerful and can generate cutting forces ranging anywhere from 50,000 lbs to 300,000 lbs or more. Different blade configurations are used by different manufactures but the most common is the C style blade in regular cutters, to a straight blade to the guillotine blade. Below are pictures of typical cutters. The tool on the bottom of the left picture is a specialized cutter that can be used in confined spaces. The cutting forces are significantly lower than conventional cutters but they have the advantage of being smaller and lighter.

Another style of cutter is the guillotine style of cutter. This type of cutter uses a hardened blade, on the end of a ram that is pushed through the material to make the cut.

Spreaders

Spreaders can come in different sizes with differing spread distances that can range anywhere from a 16 inch to a 40 inch spread. The spreading forces range anywhere from 30,000 to over 90,000 lbs. These tools can also be used as a pulling tool when used with chains. A common misconception with these tools is that as the spreader arms increase in length, the more spreading force is gained; this is not the case. The majority of the spreaders force is near the center bolt, so simple geometry shows that the farther away you get from the center bolt, the more power you lose. Just as there are different cutter blade designs, so too are there different spreader arm designs. Below are a few examples:

Rams

Rams are pushing tools that have a pushing forces that range anywhere from 30,000 to 70,000 lbs. Their extending distance can range from 20 to 60 inches. Some have a single rod that extends from the cylinder; others are telescoping to allow further travel distance. Some are outfitted with heads that can be removed to allow for different attachments such as extension rods, different shaped heads and heads that allow the tool to pull with chains. The next page shows a few examples of rams from different manufacturers.

A tool that is commonly used in conjunction with a ram is the rocker panel brace. These come in different sizes and can be of the home made variety or made by a tool manufacturer that is to be used specifically for their tools.

Brace designed by manufacturer

Home made brace

Combination cutter/spreader

These tools have cutting blades integrated into the arms of a spreader. Spreaders have significant closing forces, so the addition of cutting blades to the inner portion of the spreader arms makes these tools very popular. This combination provides a department with a more versatile tool at a reduced cost. This versatility comes at a cost, however; these tools have less spreading and cutting force than a separate spreader and cutter. Also, because the design of the blade, this tool has some difficulty

cutting through posts or round objects. The C shape design of a traditional cutter blade pulls the material toward the portion of the tool that has the strongest cutting force, the center bolt. The design of the straight blade can cause round objects such as posts to be pushed away from the center bolt and out of the blade as it closes. But, if cost is a major consideration when purchasing tools, a department may chose a combination or combi-tool as an option. The following pictures show some of the different combi-tools of different tool manufacturers.

Power plant

The final component for a hydrauilic extrication equipment set is the power plant. Power plants are more commonly 4 stroke gas engines that range from 2 horsepower single stage gas pumps that can operate only one tool to10 horsepower two stage diesel pumps that can run four tools simultaneously. There are even electric pumps that are smaller and designed for departments on a budget.

Lifting equipment

There are many different tools that can be used for lifting heavy loads. Some lifting tools are specifically made for emergency services; some are common tools that can be purchased at your local auto parts or hardware store. Regardless of which tool is used, constant training and a solid understanding of the tools limits are required.

Airbags

Airbags are probably the most commonly used pieces of lifting equipment in the fire service. They come in different shapes and sizes, have different lifting capacities and are constructed of different materials. Some bags can lift as much as 40 tons, others much less. Some low pressure systems operate with as little as 14 psi., some high pressure systems operate with 120 psi. Even with these differences, all bags need common equipment to operate: an air source, a pressure regulator, a controller and hoses to make all the connections. The following pictures show different types of airbags and their associated equipment.

A recent innovation in high pressure airbags is the flat form bag. This type of bag retains a flatter surface when fully inflated. This allows more of the bag's surface area to remain in contact with the object being lifted which then makes the lift more stable. Also, the flatter surface resists rolling and shifting common with traditional bags because these bags don't "round out" as the bag inflates.

The design of these bags allows them to retain more of their rated lifting capacity when fully inflated. The traditional high pressure, when fully inflated, turns in a round ball. Because of the way the traditional bag inflates, less of the bag remains in contact the higher the bag is inflated, making the lift less stable. The maximum lifting capacity of the traditional bag is usually reached withing the first few inches. As the bag is inflated, the amount that the bag can lift decreases significantly.

Jacks

As rescuers, we tend think that the only tools that can be used on emergency scenes are tools that are created specifically for the fire service. However, some of the most effective tools are common everyday tools that are readily available to anyone. One of these tools is the carjack. This tool is very effective because of it's quick set up and ease of operation. Nearly everybody has used a car jack so there is little need for specialty training. And finally, car jacks are relatively inexpensive, compared to other fire based rescue equipment. Two types of car jacks that are useful for extrication are the quick lift service jack and the high lift jack.

Cutting Tools

Occasionally our hydraulic cutters will not be able to cut through the reinforced areas of vehicles. When this happens, alternative tools will be needed. These tools can either be gas, electric or air powered. Regardless of which tool is used, rescuers must know their strengths and weaknesses prior to using them. Rescuers need to train with these tools; the first time that they are used should not be on the scene of an emergency. Some, but not all, of the more common cutting tools are pictured below, clockwise from the top: circular saw with metal cutting blade, air chisel and components, Skill saw with diamond blade, reciprocating saw.

Circular Saw

The circular saw is an extremely effective cutting tool. If equipped with the proper blade, usually a metal cutting abrasive blade, this saw can cut through some of the strongest steel used in today's vehicles. There are many different brands on the market, all being very strong and durable. A disadvantage to this tool is that it creates a tremendous amount of sparks when cutting. Obviously, this can be a major safety issue if there is a fuel leak involved. Another disadvantage is that it is extremely loud, especially when the blade comes in contact with the vehicle. This loud noise can cause the patient, who has just experienced a terrifying accident, to become even more distressed and uncooperative. Any noise created by extrication operations is amplified to a person inside the vehicle. These issues must be considered before rescuers decide to implement this saw.

Air Chisel

The air chisel is very effective at cutting through the vehicle's sheet metal shell. They can be equipped with different tips to cut through different types of materials. Air chisels can utilize the same regulator, hose and air source as some high or low pressure air lifting bags. One major disadvantage to this tool is its limited cutting capacity on metals other than sheet metals. Also, if the tool is being used on a metal of any significant thickness, it will burn through its air source very quickly. Another negative is that it is also extremely loud. As stated before, this noise can increase a patient's anxiety.

Skill saw

This is another tool that can be used in multiple scenarios that range from extrication to overhaul. If equipped with a diamond impregnated blade, this saw is capable of cutting an entire vehicle in half. Again, as with any other saw, it is extremely loud and can create a tremendous amount of sparks.

Reciprocating or Recip Saw

A reciprocating saw, equipped with a metal cutting demolition blade, is another tool that is effective at cutting some exotic metals by using a blade that moves in a back and forth (reciprocating) motion. These saws can either be portable, using rechargeable batteries, or electric, requiring the use of an electrical source. Departments that operate in extreme weather conditions might choose an electric saw as extreme weather can shorten battery life. Which ever type is used, a strong all purpose blade that can cut through multiple materials should be used; such blades, commonly referred to as demolition blades, can be found at your local hardware stores. There are other blades for sale that are specifically marketed for emergency services; these blades, sold as "Rescue" blades, are usually sold at a higher price. Rescuers can expect to replace blades after completing the cut, even with these specialty blades. Rescuers must use caution with this blade when cutting near a patient. Because of the motion of the blade, there is the possibility of the blade catching and cutting the patient.

Lighting

Every truck should be equipped with some type of lighting for night operations, whether it be portable or fixed to the truck. Certain accessories will also be needed to make connections. These connections can include junction boxes with multiple outlets, adapters and extension cords. Departments can choose the accessories that best fit their needs.

Lighting Equipment can be divided into two categories; fixed lighting and portable lighting. Portable lighting is used when fixed lighting is not able to reach the scene or when additional lighting is necessary. Portable lighting power may be supplied by a cord from a power source or be self sufficient as in a gas powered generator. Fixed lighting is mounted to the truck and their main function is to provide overall lighting to the scene.

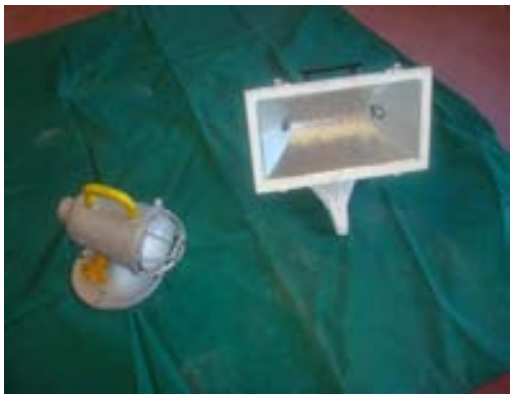
Portable lights

These lights are very useful because they can be easily transported from one spot to another. Often times gas powered portable lights can also be used as generators, even though their power generating capacity may be limited. One disadvantage to a gas powered light is that it produces Carbon Monoxide, so its use indoors would require the use of an SCBA. Some portable lights are powered by truck mounted PTO driven generators. These lights could be connected to junction boxes so that multiple lights can be powered by one source. Each type of portable light serves its own function and has its place, a combination of both gas and electric powered lights would serve a truck company well.

Gas powered portable light

Truck powered portable lights and accessories

Portable lights



Truck mounted cord reel

Twist lock to three prong adapters

Junction Boxes

Truck mounted fixed lighting

These lights are more powerful than portable lights and are usually mounted to the side of the truck or on the aerial platform. Lighting can also be mounted on an articulating or telescoping arm that is attached to the top of the truck. They are powered by the truck mounted PTO driven generator and can be designed in many different configurations.

Roof mounted articulating or telescoping lighting

Truck mounted scene lights

Truck mounted telescoping light

Platform mounted telescoping lights

Miscelleneous tools

These tools are common every day tools that can come in very handy for specific tasks involved in extrication. These tools can be pry bars which could be used to pry the hood to gain access to the batteries, wire cutters to secure the battery cables, knives to cut seat belts, chains to pull steering colums, channel locks, window punches, nut drivers and ratchet and socket sets. All these tools can be used quite effectively for different tasks. Some of them are small enough to carry in the pockets of turnout coats and pants.

Personal Protective Equipment

Finally, the most important equipment to be used on any emergency scene is a rescuer's PPE. The minimum PPE required is head, eye and hand protection, turnout coats and pants or some other type of body protection and steel toed boots with puncture resistant shanks in the soles. Jumpsuits are gaining popularity with some departments. They provide less thermal protection than turnouts but are lighter in weight which keeps rescuers much cooler than turnouts. Rescuers must weigh the pros and cons of each to decide which level of protection that they wish to use. Each piece of equipment serves its own purpose and should perform to minimum standards.

It's important to remember that there isn't one brand of tool that will accomplish everything you need. Every tool, no matter what the salesman will tell you, has limitations. When purchasing tools, departments should decide what tool capabilities fit their individual department needs prior to making a purchase. Which ever tools are purchased, constant training is needed to operate them effectively. Learning the tool's strengths and weakness on a training exercise can only make on scene operations smoother. It is much easier to learn these things in a controlled training atmosphere and to correct these issues when they occur versus finding out on scene that your tools can't handle a certain evolution. The person that suffers the most in the end is the patient. Know what your tools can and can't do, practice like you play and your on scene effectiveness will reflect your professionalism.