HOW A BALLOON WORKS

It is important to note that the Montgolfier brothers did not know exactly how their balloon worked. They erroneously assumed it was a smokey gas that made their first hot air balloon fly and referred to it as **Montogolfier Gas or Phlogiston**. Of course, it is well known today that it was the heated air inside the Montgolfier hot air balloon that made it ascend. The heat generated by the fire under the balloon made the air inside the balloon less dense than the air outside, causing it to rise.

When air is heated, the air molecules move faster and faster. They push each other away, causing the air to expand and take up more space. As the air expands, the molecules become more spread out and there are fewer molecules in the same amount of space. So the air in that space weighs less than it did when it was cooler, and it also exerts less pressure on the earth. Cold air molecules are packed closer together, so cold air weighs more and puts more pressure on the earth.

Buoyancy of the Air

The mathematician and philosopher *Archimedes* first quantified the concept of buoyancy:

> *An object immersed in fluid experiences a buoyancy force that is equal in magnitude to the force of gravity on the displaced fluid.*

To understand how balloons rise, it is necessary to understand what happens to the air both inside and outside the balloon. In hot air balloons the air inside the balloon becomes less dense when it is heated by the burner. Since the air inside the balloon is less dense than the outside air, the balloon will begin to rise. It is necessary for the pilot to continually reheat the air since colder air is denser and will cause the balloon to lose altitude. A gas balloon is filled with a lighter than air gas such as helium or hydrogen and will rise when the gas displaces the same amount of air outside the balloon. Because of these changes to the air, a gas balloon will get larger as it rises. At some point it is necessary to vent some of the gas through the valve opening to keep the balloon from bursting when it reaches capacity.

Archimedes' Principle applies to bodies immersed in air as well as to bodies in water. Thus, a body which is weighed by means of a spring scale first in air and then in a vacuum will be found to weigh somewhat less in the former case because it is buoyed up by the air about it. The apparent loss of mass of the body when in air, is exactly equal to the mass of the air displaced by it. Since air is very light, this difference in mass is usually extremely small. However, large, hollow bodies, such as dirigibles, actually displace somewhat more than their own weight of air, which explains why they float in air. Since the air is less dense at higher altitudes, a balloon ultimately stops rising at a level where the weight of the air it displaces is exactly equal to its own weight. This is called *equilibrium.*

Over the centuries, balloonists used a variety of gases to fuel their craft. These included *smoke, hot air, hydrogen, coal gas, helium and ammonia.* As we discovered in the first balloons section, the Montgolfiers thought it was smoke that made their balloon rise. Smoke balloons surfaced again in the barnstorming days of the 1800s. These were used simply as a mechanism to transport parachutists into the sky. Once Jacques Charles discovered the existence of hydrogen, it became the most often used lifting gas for many of the sport and scientific balloonists and is still used today in the C*harlière and Rozière* balloons.

At the turn of the 19th to the 20th century, coal gas replaced hydrogen as the lifting gas of choice. By this time most cities were using coal gas to heat and light homes and businesses. The gas was plentiful and

cheap and easily accessed by tapping into the lines to the underground tanks. Of course, hydrogen and coal gas had one drawback; they were highly flammable. Hydrogen is still used in Europe but helium has largely replaced hydrogen in the United States. Helium is found almost exclusively in the oil fields of the southern US and is very expensive. Even though the lifting capacity of helium is 8% less than with hydrogen, the tradeoff of not being flammable is worth the difference to some pilots. Ammonia is a relatively new gas for balloons. It, too, is not combustible and much cheaper than helium, but is very dangerous if inhaled.

The Modern Balloon

The Envelope

During the latter half of the eighteenth century, the art of fabric weaving and production of quality paper had improved greatly from earlier times. The early Montgofier balloons were laminated layers of taffeta, silk or paper secured with animal hide glue. The *gores* were attached with rows of buttons. Even when glue was abandoned and they began to sew the gores together, it was the smoke from the choking fires on board the balloon which sealed the seams and held the air inside the envelope.

When Professor Charles began work on his hydrogen balloon, he faced the problem encountered by scientists who were experimenting with this new element. Because it was so light, it was nearly impossible to contain it inside any known container. Fortunately for Charles, a recently discovered substance called rubber, presented possibilities. He was able to coat the balloon fabric with rubber dissolved in turpentine. After drying, the gores were sewn together and re-coated to ensure a tight, non-porous envelope. Today's envelopes use nylon, polyester or other light weight fabrics which are coated to reduce porosity and endure higher temperatures. The gores are still sewn together just as they were in the 1780s.

The modern hot air balloon *envelope* is usually constructed of light weight fabrics coated with both water repellant and fire resistant finishes which also retards *porosity*. Because of the FR (fire resistant) finish, if the balloon is accidentally touched by the burner flame, it will melt rather than catch fire. The envelope is made up of long sections or *gores*, sewn together and reinforced with nylon webbing called *load tapes*. Attached to the load tapes at the *throat* or the bottom of the envelope are long steel or Kevlar *cables* which attach the envelope to the *basket or gondola*. The envelope consists of the gores, a *crown or cap* at the very top of the balloon and a *skirt* which attaches to the throat. There are usually several ropes attached to the cap both inside and outside to control the balloon. The outside rope is called the *crown line* and is used by a crew person to stabilize the balloon during cold inflation. It is usually long enough that it can be attached to the basket once the balloon is fully inflated. Balloons travel horizontally with the wind, but can be controlled vertically in several ways. Since it is hot air inside the balloon that makes it rise, it is the cooling of the heated air that makes it descend. One of the ropes attached to the inside of the cap opens and closes *a vent* in the cap. By using this vent the pilot releases hot air to make the air in the envelope cooler and cause it to descend. Caps in balloons vary in design by manufacturer but are usually of three kinds, the *parachute,* the *spring top* or, in older balloons, the *side vent.* As the name implies, a side vent is a slit in the side of the envelope rather than at the top. In commercial balloons a side vent is often installed as a maneuvering vent so the balloon can be turned in the air to show off banners and company names.

Another part of the envelope is called the *skirt*. Most, but not all, balloons have a fabric skirt attached at the throat of the balloon. These have different shapes and are made of different fabrics. Some are round and some are shaped like a *scoop.* The scoop skirt is placed on the

ground during inflation to maximize the flow of air and speed up inflation. The scoop, and sometimes other skirts, are often made of a fire retardant fabric like *nomex.*

The pilot uses a rope to land the balloon by dumping the hot air completely out of the top of the balloon. This may be a separate rope called a *rip line* or *red line* or it may be part of the vent rope. When the pilot has committed to a landing, he or she pulls the red line and dumps hot air, bringing the balloon to a complete stop and ultimately, *deflation.*

The Gondola (Basket)

Most modern hot air balloon baskets are made of *wicker* or *rattan.* The basket houses the *propane fuel tanks*, the *flight instruments* and the *burner* on uprights attached to the basket.. Some balloons also carry fire extinguishers and helmets. Instruments include an *altimeter* which indicates the altitude when in flight*, a vertical velocity indicator* to measure rates of ascent and descent *and a pyrometer* to measure the temperature in the top of the balloon. The burner generates a hot flame by burning propane stored as a liquid in the fuel tanks. When the pilot opens the *blast valve* on the burner, liquid passes through the vaporizing coils and is burned as it emerges from the nozzles in the burner. Each burner has a *pilot light* which is lighted by the pilot before beginning hot inflation and remains lit throughout the flight. Pilot and passengers ride inside the gondola. Occasionally, you may still see a balloon with a metal or fiberglass basket, but there are few of these still flying. Wicker is sturdy, flexible and lightweight and will “give” on landing, helping to prevent injury or damage.