Rebuilding the Zeppelin: Power of Lifting Gas

(Scientist 1)

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11th and 12th Chemistry

October 22, 2021

Rebuilding the Zeppelin: Power of Lifting Gases

Imagine an ideal, industrial world where people work to have resources gathered, reproduced, and transported to the far ends of the earth. This sort of beast would have the responsibility and capacity to carry the main transportation system on its back. Massive storage containers are flying through the sky hauling goods over any terrain and arriving at their appointed destination in a timely, efficient manner. This majestic creature is the airship.

Background Information

The effectiveness of airships greatly depends on how much weight they can carry. After all, its massive weight payload being carried across the sky is its greatest and most prominent attribute. The lighter the air used in an airship, the more weight it can carry. It must be determined how much lighter each gas is and what is more ideal to use. There is also the angle of safety to consider. Some gases are highly explosive, so it must be determined how to reduce the risk of destruction. Efficiency must also be balanced with risk. The most practical solution must be found to determine what sort of gases should be used in an airship.

Terms and Definitions

A few terms must be understood before there is further investigation. An airship can be described as “a self-propelled, lighter-than-air aircraft with means of controlling the direction of flight; dirigible” (Dictionary.com). Buoyancy is a natural law of the world. It is “the force that causes objects to float. According to the principle of Archimedes, when a solid is placed in a fluid (a liquid or a gas), it is subject to an upward force equal in magnitude to the weight of the fluid [or gas] it has displaced” (Dictionary.com). Combustion and explosion might sound the same, but they are distinctly different. “Combustion is a chemical process in which heat is produced and used in some chemical process. Combustion is done by reaction between a fuel and

an oxidant. The resulting heat can produce flame" (What is the Difference). It is only an explosion if there is a loud sound emitted by the reaction, which is caused by a sudden, violent burst of energy "due to generation of high temperature...It produces a shock wave" (What is the Difference). Combustion is more of a flame while an explosion has much more destructive force, so when looking for safety, combustion is preferable. A reducing agent is "A substance that chemically reduces other substances, especially by donating an electron or electrons" (Dictionary.com). "Hydrolysis is a common form of a chemical reaction where water is mostly used to break down the chemical bonds that exists between a particular substance" (Admin). Hydrolysis is a method commonly used in the generation of hydrogen gas. Lastly, a catalyst is "a substance that causes or accelerates a chemical reaction without itself being affected" (Dictionary.com). In some methods of hydrogen generation, a catalyst is necessary to start the reaction.

Historical Context

Airships had been made before, but the zeppelins were the ones that truly revolutionized the world of the 20th century. A man named Count Ferdinand von Zeppelin hypothesized that a light gas had the potential to allow a large airship to fly, which was proven correct. Zeppelins used buoyancy to successfully achieve flight. They could lift an immense amount of weight and were described as a "movable, floating shed" that could be steered to a desired location. (Grossman)

There were four predominant early zeppelins that launched airship technology forward: the LZ-1, LZ-2, LZ-3, LZ-4 (Grossman). The LZ-1 was Zeppelin's first working airship. It utilized hydrogen gas to act as a lifting gas, but it was exceedingly heavy and uncontrollable in the winds. The predominant advancement of the LZ-2 was the addition of triangular girders to

dramatically increase the airship's rigidity and strength. "The next two ships, LZ-3 and LZ-4, were even greater advances in technology, with huge increases in controllability, power, speed, range, and payload" (Grossman). Aerodynamic fins and a sort of rudder at the back which greatly improved the stability and lift. The airship could now last a full, twelve hour flight. More models continued to be built and the technology continued to improve. There were plenty of failures and even some crashes but they continued to be built and refined. It lost steam, however, when the Hindenburg Disaster was one of the first crashes ever caught on film.

Hydrogen is the first element on the periodic table, having an atomic number of one and a mass number of one (Hydrogen). Hydrogen has one valence electron and shows a valency of plus one (Hydrogen). It is unique because it has only one electron and one proton (Granger). "Hydrogen is a colourless, odourless non-metal" (Granger). It often combines with other non-metals to form compounds such as hydrochloric acid (HCL), water (H2O), hydrogen sulfide (H2S), and some others (Hydrogen). It is also an effective reducing agent. Hydrogen is the lightest and most common element in the periodic table (Hydrogen). Hydrogen gas, however, is not really present as an aerosol in the earth's atmosphere. Due to the nature of its valence electrons, it easily bonds with other materials, so it is commonly found in compounds such as hydrochloric acid (HCL), water (H2O), hydrogen sulfide (H2S), and many others. Two of the most useful attributes of its gaseous form are how light and combustible it is. Because hydrogen is much lighter than air, it is an excellent resource for gaining altitude.

Key Scientists

Count Ferdinand von Zeppelin was the father of the multi-generational Zeppelin (Grossman). He was born in Germany on July 8, 1838. He was trained at the military academy at Ludwigsburg and soon became an officer in the army at the age of 20. He was a military

observer in America during the Civil War. In his time there, he looked upon the first balloon he had ever encountered and took a trip into the sky with it. His almost ethereal experience floating in the heavens peaked his interest in airships. He then made plans and designs for lighter than air, rigid, steerable airships, and went through multiple stages of Zeppelins.

There is a man who should also be given his due credit and his name is Ludwig Dürr. Ferdinand von Zeppelin would not have been able to do all that he accomplished without the help of his brave and trusted engineer Ludwig. He was the chief designer and engineer for almost every airship built by the Zeppelin Company. He was trained as an airship pilot and was in charge of flying several of the early Zeppelins (Grossman).

In 1671, a British scientist discovered the existence of the element of hydrogen (Granger). This brilliant man was named Robert Boyle. He found this out by conducting a single-displacement reaction using potassium and hydrochloric acid (Granger). The result was a solution of potassium chloride and hydrogen in its gaseous form (Granger). He knew that it existed. This was the reaction:

$$2K + 2HCl \rightarrow 2KCl + H_2$$

A little over a century later, yet another British scientist called Henry Cavendish confirmed hydrogen as a distinct element in a methodical and analytical paper. Both scientists observed the flammable nature of hydrogen gas and exothermic reaction that can occur (Granger).

$$2H_2 + O_2 \rightarrow 2H_2O \text{ (+ Heat)}$$

Problem

Airships need enough gas lighter than air to be able to leave the ground. It needs to be light enough to carry the rigid frame in addition to any extra cargo. The lightest and most effective gas to use is hydrogen gas. Unfortunately, this gas can be dangerous especially when it

is paired with oxygen and an ignition, which causes an explosion. This is why helium is used instead most often to make objects float. Unfortunately, this lighter-than-air gas is slowly being depleted and released into the atmosphere where it currently cannot be retrieved (Helium Depletion). Helium is found in the limited supply of specific rocks it comes from. For some things, there is no replacement for helium due to its unique properties where it is used in cooling superconducting magnets in MRI scanners, fiber optics, and other uses (Helium Depletion).

When comparing hydrogen and helium gas to one another, within the grounds of using these different gases as a lifting agent in airships, it is clear that helium is a much safer option, but when working with weight, hydrogen is lighter than helium, and it is far easier to produce. If the airship was carrying cargo and exploded, it would not be that bad, but if the airship was transporting people and exploded, the backlash would be horrendous.

Globally, if hydrogen was used instead of helium, our already limited and diminishing supply of helium would last much longer. Regionally, the use of the airship would improve the economy of nations using this method. On a community level, shipping would be far cheaper for businesses, and less fossil fuels would be used. Personally, the cost of shipping would be far cheaper for every individual.

Science of Problem/Question

There are 3 predominant methods of the hydrogen gas production, and they are hydrolysis, the combination of hydrochloric acid and zinc, and the combination of water, aluminum, and lye which is sodium hydroxide.

Electrolysis is essentially the breaking apart from atoms by sending an electrical current through them so that the atoms will get pulled apart and become separate. “This reaction takes place in a unit called an electrolyzer” (Hydrogen Production). It is the breaking down of

polymers into monomers (Admin). Hydrolysis is a more specific form of electrolysis that involves the separation of the water molecules into its parts. Hydrolysis is a word derived from the Greek language with *hydro* meaning water and *lysis* which means to break or unbind (Admin).

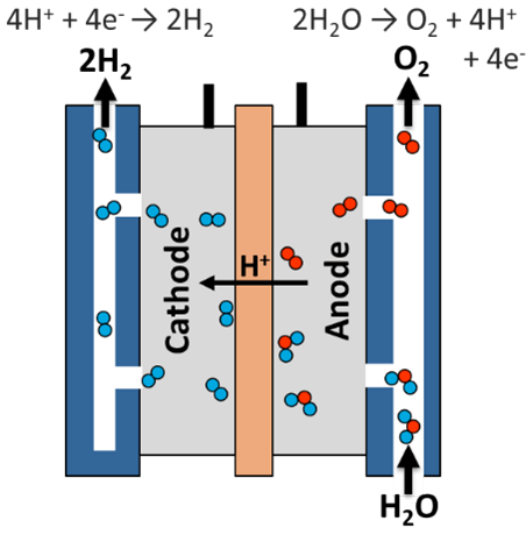

Figure 1: "How an electrolyzer works" (Hydrogen Production).

Electrolyzers have an anode and a cathode which is separated by an electrolyte (Hydrogen Production). The electrolyte membrane that separates the anode and cathode is usually a type of plastic material (Hydrogen Production). Anodes are commonly metals such as zinc or lithium and oxygen bubbles usually form around this side, while at the side of the cathode, which is graphite, copper or some sort of material that easily gives out electrons, the hydrogen ions combine with the given electrons to form hydrogen gas (Hydrogen Production).

Anode Reaction: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Cathode Reaction: $4H^+ + 4e^- \rightarrow 2H_2$

The chemical equation for the chemical reaction of zinc and hydrochloric acid to create hydrogen is:

$$2\ HCl + 2\ Zn \text{ ---> } H_2 + 2\ ZnCl$$

When hydrochloric acid comes into contact with zinc, the chlorine from the hydrochloric acid will jump to the zinc and bond with it (DIY Hydrogen Gas). It then will result in zinc chloride (ZnCl) and have a byproduct of hydrogen gas, so theoretically the more zinc in the solution, the more hydrogen is released from the hydrochloric acid. (DIY Hydrogen Gas)

The chemical equation for the chemical reaction of water and aluminum to create hydrogen is:

$$2\ Al + 6\ H_2O \text{ ---> } 2\ Al(OH)_3 + 3\ H_2$$ (DIY Homemade Hydrogen).

Upon contact with aluminum, the solution will turn into aluminum hydroxide and release a byproduct of hydrogen gas (DIY Homemade Hydrogen). In theory, the more aluminum in the solution, the more hydrogen is released from the water, which produces more hydrogen gas. (DIY Homemade Hydrogen)

Accepted Measurement Practices

We test how much each gas can carry. To test how much weight each gas can hold, more and more weight will be added until the container does not float anymore. One way of testing the purity of the hydrogen gas is by running it through a hydrogen purity analyzer, but if that is not accessible, there is another way. A second method of testing hydrogen purity is transferring the generated gas into test tubes that hold the air. When a flame is placed near the gas-filled tube, it will make a “POP” sound that will vary in volume depending upon the percentage of hydrogen and oxygen in the test tube. The louder the sound, the more explosive and dangerous it is. A decibel meter will numericize and quantify the test data and improve its accuracy and precision.

Limitations of Practices

The weight test is pretty straightforward; just see how much weight the gas can hold up before falling to the ground. There is clear numerical data that directly answers the question. When testing the hydrogen with a hydrogen purity analyzer, it will just show the purity percentage, and not how explosive the gas is. But if the ignition in the test tube method is done, the sound is tested, which indicates how much of an explosion there was. Even if there are exact margins, it still needs something to be based off of. One definite possible lurking variable is the environment where the sound is tested can affect the reader. Distance from the explosion would have to be the same in all tests.

Current Research

Currently, there is a company titled Lockheed Martin that works on a multitude of different aerospace projects and designs. They have been working on hybrid airships for over 20 years and continue to refine their performance and their technology (Hybrid Airship). They are strong advocates for the widespread implementation of airships. “Hybrid Airships make it possible to affordably deliver heavy cargo and personnel to remote locations around the world. Burning less than one tenth the fuel of a helicopter per ton, the Hybrid Airship will redefine sustainability for the future” (Hybrid Airship).

Conclusion

Airships were designed, tested, and improved, over the course of many years. However, since the crash of the Hindenburg, the popularity of airships plummeted. This is unfortunate because there is so much untapped potential in airships.

Currently, there are two problems that need to be addressed for the airship. It must use a gas that carries enough weight for its use to be practical, but it must also be safe enough to use to transport commodities and people. A balance must be found between the efficiency of weight

carrying capacity and the risk and danger of the gas used. If airships used an easily producible gas, then the crisis of the diminishing supply of helium will be averted for the time being. It will affect the world and even an individual's life financially, with transportation and shipping costs. Also, the mixture of both hydrogen and helium within one container should be investigated.

The airship has specific flaws that it needs to work past. These weaknesses are being addressed and worked on right now. Different methods of pure hydrogen production are being discovered, tested, and pursued to overcome these trials to lead to a path of victory and success where this enormous warehouse can safely ferry an immense amount of weight.

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This webpage provides the essential information to know about the element of zinc. It talks about the alloys that it is used in and what modern products are produced with it. It explains what physical and chemical properties it has. This is a webpage of verified university “Elmhurst University.” Since zinc is used in a chemical reaction that produces hydrogen gas it is important to know what it is and why it happens.

Admin. (2020, November 16). What is Hydrolysis? - Types of Hydrolysis, General Formula. Retrieved from https://byjus.com/chemistry/hydrolysis/

This article states and explains the equation of hydrolysis. It explains what hydrolysis is, the origin of the word, what it is used for, and the different types of hydrolysis. It explains what happens and how it happens. It is from BYJU's company which is a highly esteemed and valuable company that offers learning programs for students. Hydrolysis is a common method that is used to produce hydrogen gas.

DIY Homemade Hydrogen (Aluminum Water Lye) - YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=XEJITyXpghs

This is a video where a scientist explains how to generate hydrogen gas by having aluminum and water react in the presence of lye, which is used as a catalyst to break down the oxidized layer covering the aluminum. It shows the equation and explains why it works. This video is created by an ever studying and learning scientist. This is important because he demonstrates a process that is used to produce hydrogen gas.

DIY Hydrogen Gas (Hydrochloric Acid Zinc) - YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=diiYf26LNJ4

This is a video where a scientist explains how to generate hydrogen gas by having hydrochloric acid reacts with zinc. It shows and demonstrates the equation of how to produce hydrogen gas using zinc and hydrochloric acid. It explains the how and why. This video is created by an ever studying and learning scientist. This is important because he demonstrates a process that is used to produce hydrogen gas.

DIY Water Electrolysis Kit (Hydrogen Generator) - YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=gH-jhN3mV60

This is an excellent resource for finding a design on how to separate hydrogen gas and oxygen gas individually formed from the anode and cathode. It shows a design of the concept. It also provides visual evidence that in higher percentage, hydrogen gas is not explosive; it just burns. This scientist has performed multiple different experiments, conducts his own experiments at home, continues to be intrigued by various scientific concepts. This will be helpful in designing our own experiment.

Helmenstine, A. M. (n.d.). 4 Easy Ways To Make Hydrogen Safely. Retrieved from https://www.thoughtco.com/how-to-make-hydrogen-gas-608261

This article outlines the multiple different methods of how to produce hydrogen gas. The first way is electrolysis which essentially separates the hydrogen and oxygen molecules into their individual gas forms. The second way is a variation of electrolysis but with carbon and salt. The third way is hydrochloric acid and zinc. The fourth way is the method that uses lye as a catalyst to cause the reaction between water and aluminum. This information is provided by ThoughtCo which is the world's largest education resource. This information is essential for knowing the different methods of forming hydrogen gas. It gives different experiments to test to see which one is the best.

Hydrochloric Acid Formula - Hydrochloric Acid Uses, Properties, Structure and Formula. (n.d.). Retrieved from https://www.softschools.com/formulas/chemistry/hydrochloric_acid_uses_properties_structure_formula/224/

This resource gives detailed information all about the compound of hydrochloric acid. It details its formula, structure, and physical and chemical properties. It also tells of how it is made and what it is commonly used for and where it is naturally found. This clear page is from a trusted learning website. It is highly important to know all about a material that will be used in the chemical experiment.

Hydrogen - YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=7Om56BAxJJ4

This video could essentially be a PowerPoint that explains a plethora of information about the element of hydrogen. It details its formula, structure, and physical and chemical properties. It also tells of how it is made and what it is commonly used for, where it is naturally found, and who the first person was to find that hydrogen gas produces water when burned, amongst other various facts about hydrogen. This is vital to know, for the whole project depends on hydrogen gas or helium.

Lavoy, D. (2019, March 02). Physical and Chemical Properties for the Element Aluminum. Retrieved from https://sciencing.com/physical-chemical-properties-aluminum-element-6785380.html

This entire article basically describes and recounts the physical and chemical properties of the element of aluminum. It also tells of who first isolated the element and what the common uses for aluminum are. This is from a massive, up-to-date science dedicated website. This is necessary to know for this experiment, because we will be using

aluminum as one of the materials to produce hydrogen gas.

Hydrogen Production: Electrolysis. (n.d.). Retrieved from https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

This resource explains what hydrolysis is, how and why it works. It explains how it can and should be implemented. For example, the excess power wind farms generate should be used for electrolysis. It talks about what needs to be improved in the process. It would be most helpful performing electrolysis using renewable energy rather than electricity produced using fossil fuels. This is a page posted on a government website by The Office of Energy Efficiency and Renewable Energy. This tell of the feasibility of using the process of electrolysis.

Rebuilding the Zeppelin:

Buoyancy and the Study of Gases

(Scientist 2)

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September 30, 2021

Rebuilding the Zeppelin: Buoyancy and the study of gases

Ever since the Hindenburg went up in flames the airship industry has been mostly disregarded despite its major advantages in the cargo industry. Are the risks of study too high? Is hydrogen gas too dangerous for use? These are the kinds of questions that hold back the airship industry. There are other options when it comes to lifting gases in lighter than air aircrafts, primarily hydrogen and helium. It is known that Hydrogen is lighter than helium and therefore lifts more, but is the safety of helium worth the reduced practicality?

Historical Context

Branch of Science

This topic revolves around the gases that are used within the airship. There are different methods used to produce hydrogen, which lead to different levels of purity. Helium is also used within lighter than air vehicles and is non reactive. The proper balance must be found between safety and practicality leading to the best gas to use in a lighter than air vehicle.

Terms and Definitions

Airship is a very broad term referring to a large group of lighter than air aircrafts. Another term that is often used in the place of “Airship” is “Dirigible”. “Dirigible” is slightly more specific, it refers to a lighter than air airship that has propulsion, and is able to be steered (Webster, 2020). There are three different classifications of dirigibles. These are: Fully rigid, semi rigid, and non rigid. Fully rigid is a structured frame and covering that contains multiple gas cells (airships.net, 1997). Semi rigid is a frame and covering that is filled up directly (Airships.net, 1997). An example of the semi rigid airship is the Goodyear blimp. A non rigid airship is a specifically shaped balloon that is usually called a blimp (Airships.net, 1997). These airships are airbourne due to a force called lift. “Lift is the component of total air force on an

aircraft which is perpendicular to wind and in a plane of symmetry." (Webster, 2020). These airships are often steered and stabilized with fins. A fin is a stabilizer that is attached to the body of the vehicle that sticks out and has the purpose of directing the air to the benefit of the craft (Airship.net, 1997). The Delta fin is a specific version of the fin most often used with small rockets as well as airships. The Delta fin is a trapezoid shape in which the longest side attaches to the body of the aircraft (Apogee Components, 2021). The most important piece of the airship aside from the gas cells themselves in the gondola. The gondola is the part of the airship dedicated to the carrying of people and the payload of the airship (Webster, 2020). The payload is the load carried by a vehicle that is exclusive of what is necessary for the operation (webster, 2020).

Historical context

Airships have a long and complicated history starting with large balloons used to scout out the enemy in battles. These balloons were tethered to the ground with long ropes and had no way to control their speed or direction (Britannica, 2020). It was Zeppelins research and production that launched the new era of Lighter than air aircrafts. He went from model to model improving his design culminating in the LZ-129 (Airships.net, 1997).

All along the way these lighter than air vehicles were using hydrogen. The question of safety came in with the crash of the Hindenburg (LZ-129) in 1937 (Airships.net, 1997). Hydrogen is a reactive element that acted as a fuel to the blaze of the Hindenburg. This is the accident that essentially killed the airship industry. In modern days regular balloons are filled with helium which is a noble gas so it will not catch fire.

Key Scientists

When it comes to the study of hydrogen there are multiple founding scientists that come to the forefront of historical study. In 1671 Robert Boyle was experimenting with iron filings and dilute acids. The byproduct of this chemical reaction was hydrogen gas (Libretexts, 2019). It wasn't until 1766 that Henry Cavendish recognized hydrogen as a distinct element. Cavendish, however, was not the one who named hydrogen, hydrogen was named by Antoine Lavoiser in 1783 (Libretexts, 2019).

The study of airships is a much less crowded field when it comes to major contributors. It was Archemides who first established buoyancy as a simple principle (ThoughtCO., 2020). Ferdinand Von Graf Zeppelin actually got his first aeronautical experience in large non-steerable balloons while scouting as an observer on the union side in the American Civil war (Britannica, 2020). After this he began to create airships of his own, only these airships were not stationary scouting balloons, they were aerodynamic flying machines. These air ships were also rigid in structure as opposed to the non rigid balloons used before. The first of these airships was the LZ-1 (Airships.net, 1997).

Recently the study of airships has picked back up with current research being done by two major companies. The Airlander Ten is a current model being worked on. Alongside the airlander Ten is the new design by Lockheed Martin.

Major Question

What is the most practical lighter than air gas to use in an airship? This is a balance between lifting capability as well as safety. There are multiple lifting gases such as hydrogen and helium, and hydrogen has different purity levels. This is about finding the best one to use.

Impact

The re-institution of airships will change much of the shipping industry making it easier to carry cargo from place to place. This could benefit remote regions greatly because an airship can reach all the places a helicopter can reach but it can carry the cargo load of a large boat. Making it easier to get resources into remote places. Finding the most practical lifting gas could make airships look better in the eyes of the community making them easier to reinstate.

Science of the Question

To find which gas can lift the most we will need to measure in grams. We will add weight in single one-gram units. The models will have the same starting weight because they will be made from the same material.

We are only using model airships on a small scale rather than full size airships. This does not scale up linearly. Larger airships are more practical because they have more volume capability.

Current Research

The engineering company Lockheed Martin is currently working on a hybrid airship. This as well as the Airlander 10 are examples of current research that is happening within this field of study (Lockheed Martin, 2020).B

Conclusion

The Airship industry has an interesting and full history primarily consisting of the Tireless work of Ferdinand Von Graf Zeppelin and his company. Although it ended in tragedy it should not be ruled out as a major potential for the future. The Question of hydrogen and helium is really finding the balance between safety and practicality. Finding the solution to this question

could be the first major step in re-instituting the study of airships, although some like Lockheed Martin, and Airlander 10 are already beginning the process.

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JRank Articles provide a useful historical background on airships over time. It follows the development of the airship from its early stages as a directionless balloon. It follows the airship through the experimental period of blimps. It also goes through the chronicles of airships built by Zeppelin himself. This source takes a formal approach to presenting the long and complicated history of the Airship. The expansive and broad scope of this source gave interesting historical context to the airship.

Apogee Components, I. *Apogee Components - Clipped Delta Fins with Through-the-Wall Tab*. Clipped Delta Shape with Through-the-Wall Tab. https://www.apogeerockets.com/Building-Supplies/Rocket-Fins/Clipped-Delta-Fins-with-Through-the-Wall-Tab.

Apogee components are a source primarily meant for model building, especially that of model rockets. It not only teaches the learner how to make the fins spoken of but teaches of the shape purpose and benefits to using the given fin design.This source was useful not only in the describing of the fin but also in the making of the fin in the actual experiment. This site is set up much like a class with a teacher there to both show and explain the topic.

"The World Standard in Knowledge since 1768." *Encyclopædia Britannica*, Encyclopædia

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https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-aerodynamics-58.html.

This site helps to give a formal definition to a branch of science that most know but cannot properly describe. The source is easy to use even though it is that of one of the most important engineering administrations in the world. This site presents material in a very comprehensive yet simple way. It is clearly a source meant for teaching rather than someone who already knows a great deal about the field.

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Important Announcement. Lighter Than Air, Better than Gas | College of Engineering.

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This site successfully explains the properties of lighter than air lifting gas. Lighter than air gases are a complex subject that was explained in a way that it seemed simple in its base properties, even explaining the ratios of weight that could be carried by any given lifting gas. This site was set up in a formal yet engaging way. It was entertaining and educated the learner at the same time. It gave accurate and precise information that was useful in the writing of this paper.

Lockheed Martin Corporation. Lockheed Martin.

https://www.lockheedmartin.com/en-us/index.html.

Lockheed Martin is primarily an engineering company so the fact that they have an educational site about the kind of science they explore is both surprising and exciting. They lay out some of the science behind their designs and even have a link open so that viewers are able to contact them with any questions they might have. This educational site sheds credibility on their work and allows researchers to understand better why their design looks the way it does. This is very useful information to a researcher who is studying the difference between two similar designs.