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NEWSLETTER

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Energy Conversion In a Model Rocket Flight

By Tim Van Milligan

Every school year, Apogee gets dozens of inquiries from students about the energy transformation in a model rocket launch. This article will describe all the energy transformation that goes on.

To my engineering friends, let it be known that I'm trying to write this in a way that younger students might understand the complex process that takes place, so it may not quite sound technically accurate. But it is close enough.

Where does the Energy Come From?

All the energy for a rocket launch comes from four sources. The first three are the rocket engine, the igniter pyrogen, and the controller's battery. In these instances, it is stored in the form of chemical energy. The fourth form of energy is what you provide when your thumb presses on the launch button.

The process starts with the chemical energy stored in your muscles. Your muscles convert this to mechanical energy when you push on the launch controller's ignition button. This switch completes the circuit, and the chemical reaction in the battery starts. The chemical reaction frees up electrons, which then flow through the wires to the igniter.

Inside the igniter, buried within the pyrogen on the tip, is a very thin wire made from nichrome **(Figure 1)** www.ApogeeRockets.com/Rocket-Motors/Motor-Starters/FirstFire-Mini-8in-long

This special type of metal has the property that it heats up quickly when electricity flows through it. It is the same metal that is in your toaster oven at home. In essence, it converts electrical energy into heat energy.

This heat energy provides the spark that initiates combustion of the pyrogen on the tip of the igniter. Combustion is a process of liberating the energy in the burning material. The pyrogen, like the propellant in the motor, have energy stored within them. It is released when the chemical reaction of burning takes place. The energy is released in the form of intense heat.

This heat energy from the burning pyrogen is transferred to the surface of the propellant. The propellant gets hot enough to also start burning.

In a combustion process (a chemical reaction), matter cannot be destroyed, so the particles of matter that make up the propellant are still there inside the rocket motor. The form of the particles is a hot gas. So the heat energy that is released from the combustion process gets the particles moving (vibrating). That is what heat is, an intense vibration of the particles. In essence, the heat changes to kinetic energy of the moving particles.

Figure 1: Close-up of a FirstFire Mini igniter. The pyrogen on the tip covers the nichrome wire.

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About this Newsletter

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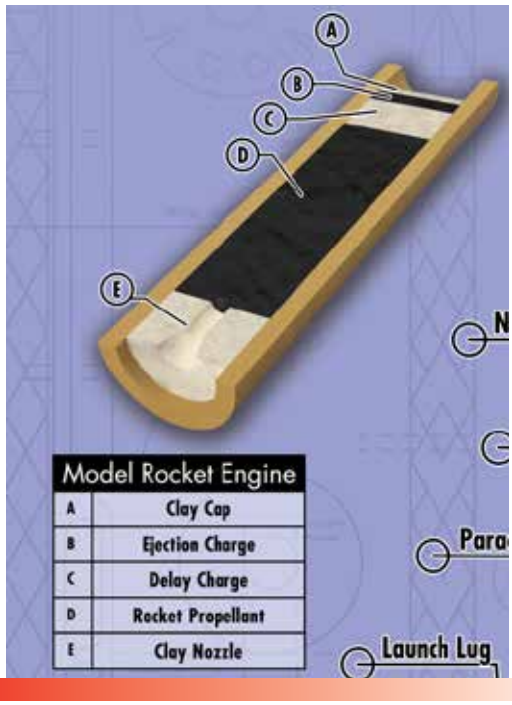

Figure 2: Cutaway of a rocket motor from our Model Rockets Components Poster. The "E" label shows the opening in a model rocket engine where the particles escape.

The particles are trapped in the rocket engine's combustion chamber, and the pressure inside the motor increases. But fortunately, there is an opening in the motor called the nozzle **(Figure 2, Rocket Components Poster)** www.ApogeeRockets.com/Rocket-Books-Videos/Posters/Model-Rocket-Components-Poster, so there is a way for those particles to escape. The particles flow out the nozzle. The shape of the nozzle is important, because the purpose of the convergent/divergent shape is to increase the speed of the particles as they flow out the back of the rocket. We need the speed of the particles to be as high as possible - to maximize the kinetic energy of the tiny particles of gas. The speed is important, because it determines the level of thrust the motors makes.

The thrust force is what pushes the entire rocket into the air.

Figure 3: Rocket flame (light energy) from the Star Lift Mega Lander Rocket as it takes off.

Now we've got the kinetic energy of the entire rocket - 1/2 x m x V2. The faster the rocket goes, the higher the kinetic energy. The maximum energy level occurs near burnout, when all the propellant has been consumed by the combustion process.

It should be noted that some of the chemical energy is also converted to light energy of the rocket flame in the exhaust. This light energy in the flame doesn't affect the speed of the rocket, so it is a waste product of combustion **(Figure 3, Star Lift Mega Lander)** www.ApogeeRockets.com/Rocket_Kits/Skill_Level_5_Kits/Star_Lift_Mega_Lander .

As the rocket rises up in the sky, the kinetic energy of the rocket's motion is being converted to Gravitational Potential Energy, which is a stored energy of height above the

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ground. Eventually, all the remaining kinetic energy of the rocket that isn't lost to friction drag as it slides through the air will be converted into potential energy as the rocket coasts up to the top of its trajectory, know as the 'apogee' point.

As the rocket begins to fall back to the ground, the potential energy is converted back into kinetic energy. The rocket gains speed as it falls back to earth **(Figure 4, Model Rocket Flight Phases** www.apogeerockets.com/Edu/Rocketry_Reservoir**)**.

If the parachute fails to open, the rocket will continue to gain speed, and impact the ground. All the remaining kinetic energy of the rocket is released into the ground as the soil shifts and the rocket body is deformed. There is some heat from friction that is also created as the soil shifts. This heat energy is absorbed by the surrounding soil and the air above the ground.

Of the four forms of energy input into the system, only the stored energy of the rocket engine is used to move the rocket. Everything else is just to get the combustion process of the propellant started.

Energy Loss

During the flight the goal is to convert all the chemical energy from the motor into kinetic energy of the motion of the rocket. Unfortunately, a lot of the chemical energy of the propellant is wasted during the flight.

A lot of the heat energy created by the propellant does not go into the particles moving out the nozzle. Some of the energy is absorbed by the rocket casing. You probably felt this when you picked up the rocket after launch. Rocket motors make nice little hand warmers on cold days.

There is a little bit of friction of the rocket sliding up the launch rod. This friction is in the form of heat energy. The rod gets a little bit warmer, and eventually cools as it is radiated away to the surrounding air. And another little bit is lost

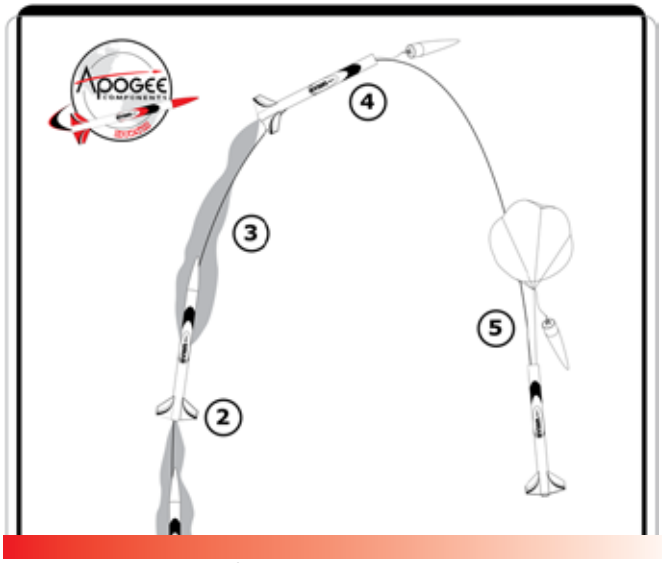

Figure 4: (Page 4 of The Rocketry Resevoir) Stage 4 is where the model rocket hits Apogee and begins to fall back to earth.

as light energy emitted from the rocket flame.

The majority of energy lost is in the form of air friction called drag **(Figure 5, Advanced Construction Video 217** www.ApogeeRockets.com/Advanced_Construction_Videos/Rocketry_Video_217**)**. The kinetic energy of the rocket moving is converted to heating of the air surrounding the rocket as it moves through the air. As long as the rocket is moving, it is losing energy to the air in the form of friction drag - both on the way up and on the way down.

Figure 5: Screen shot of our Advanced Construction Video 217. The wavy lines represent the air going around the rocket and creating drag around the nose and fins.

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Conclusion

By the time the rocket has touched down, there is no energy left. All of it has been dissipated to the atmosphere. It is my hope that the mission of the flight was worth the expenditure of the energy. Did you achieve the speed or altitude anticipated from the flight? Did you collect good data from any experiments you carried in the rocket? Was the mission a success? Did you do something impressive? Did you learn something from the flight? All of these are used to define the success of the mission and the expenditure of energy it to accomplish it.

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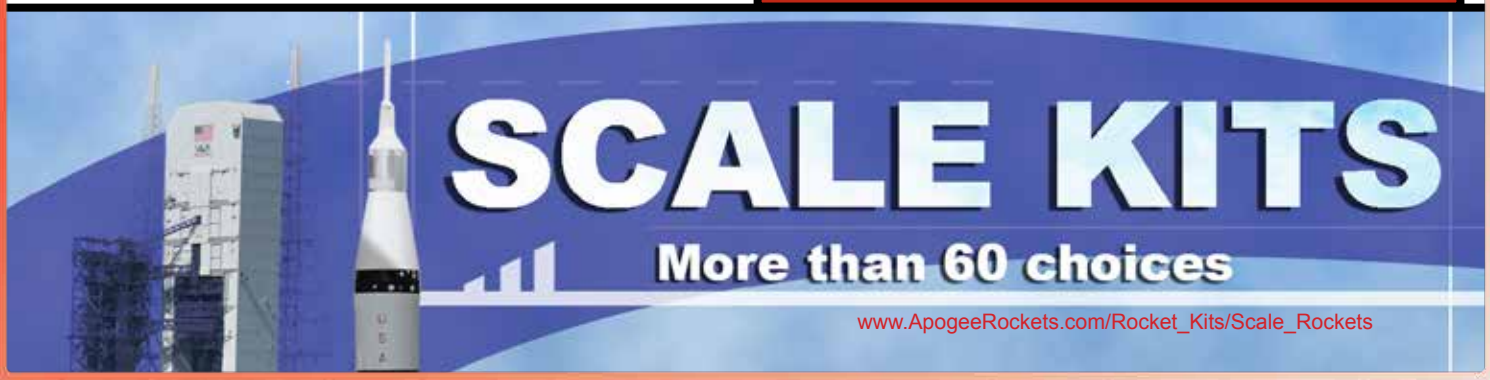
Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor, and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: "Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics" and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at: https://www.apogeerockets.com/Contact.