

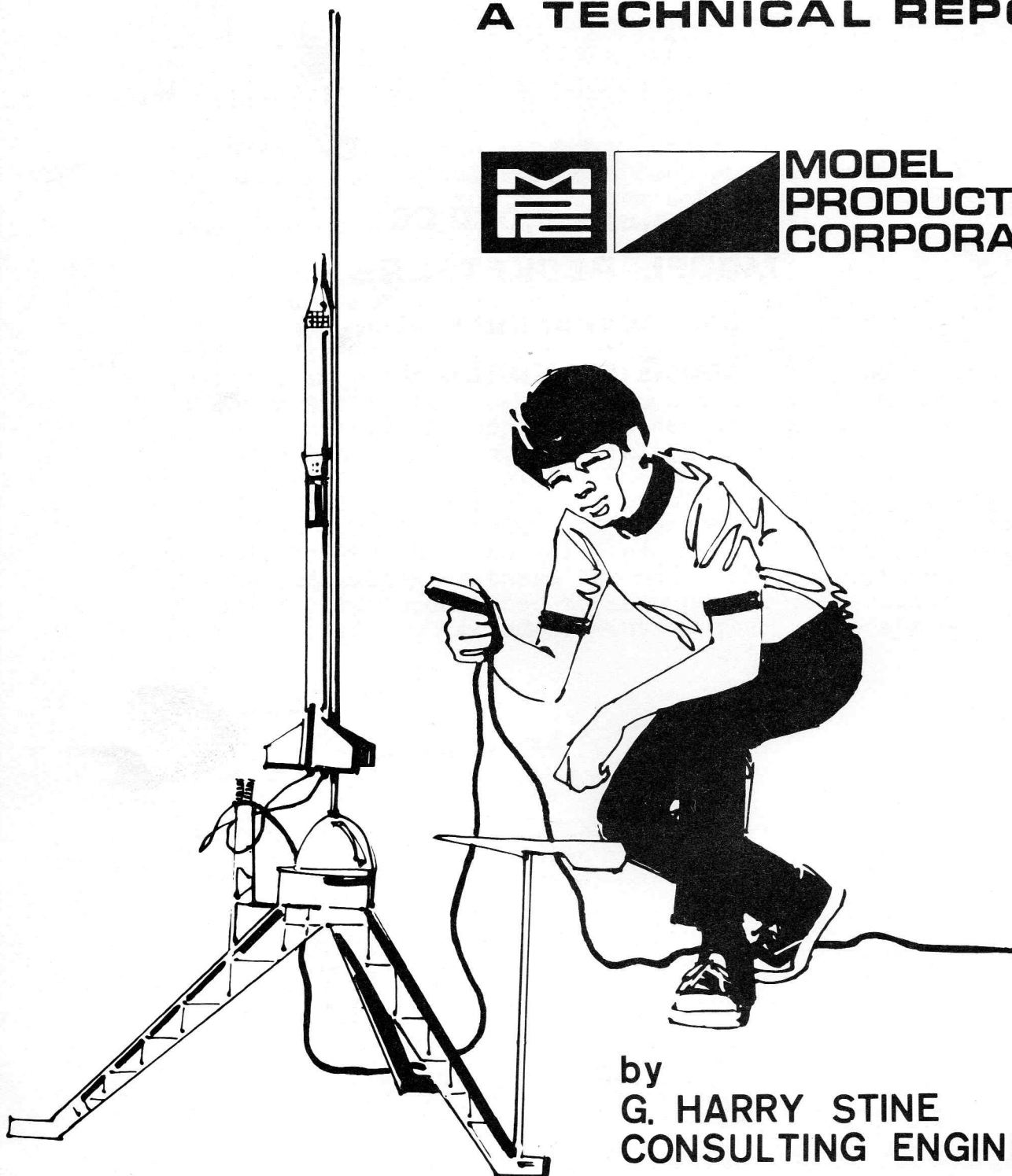
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MODEL ROCKET SAFETY

A TECHNICAL REPORT



**MODEL
PRODUCTS
CORPORATION**



by
G. HARRY STINE
CONSULTING ENGINEER

TO
America's 1,000,000
MODEL ROCKETEERS,
the Astronauts of
the 21st Century



Hobby Industry Association OF AMERICA, INC.

200 FIFTH AVENUE • NEW YORK, N. Y. 10010 • AREA CODE 212 WATKINS 4-4262

July 25, 1970

Gentlemen:

The HIAA believes the material contained in this book prepared by the Model Products Corporation presents a fair and accurate picture of the safety aspects of model rocketry as a wholesome hobby activity.

In the course of the past several years, it has been my pleasure and privilege to meet and talk with fire chiefs and police officials in most of our states and cities. All expressed deep interest and appreciation in receiving information about model rocketry pertinent to their particular area of responsibility. I am impressed by their spirit of cooperation, dedication and skill in a profession of a highly specialized nature.

The HIAA and the National Association of Rocketry share a mutual concern in maintaining the enviable safety record established by model rocketry over the past thirteen years. The co-ordination of these two national Associations in this activity is designed to lend utmost cooperation and support to all concerned. We invite your cooperation.

Tim Skinner

Chairman, Model Rocket Division, HIAA

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INTRODUCTION

This report was prepared specifically for those persons interested in the safety of model rocketry and model rocket engines.

Model rocketry has been growing rapidly around the world because of the tremendous interest in the American and Russian space programs and the great human accomplishments of the astronauts and cosmonauts. Model rocketry is one of the finest and most meaningful educational tools available for teaching physical science and mathematics to our young people, and it is being used with increasing frequency and great success in grade schools, secondary schools, college undergraduate studies, summer camp programs, Scout projects, and YMCA youth activities. Several park and recreation departments have also established model rocket programs and made available large flying areas in public parks.

Model rocketry has an excellent safety record, as this report will show.

Some people have misunderstood the nature and safety of model rocketry because they have not been aware of what it is and what it is doing. To mention the words "youth" and "rocketry" in the same sentence often conjures up the image of a highly dangerous experimental pastime. In this report, we hope to provide answers relating to hazards, equipment, techniques, and safety. We believe that only by providing complete and accurate information can we better inform people who are concerned.

For convenience in use, we have divided this report into two parts. The first consists of a series of commonly-asked questions and their answers, accompanied by appropriate illustrations. The second is a compendium of data for those persons interested in the specific, highly technical information about model rocketry.

In this second part, we concentrated on the most apparent hazard, the model rocket engine itself. At MPC, we conducted a series of specific, controlled, repeatable tests designed to determine what could and could not be done with a model rocket engine, whether or not it would explode and under what conditions, what it took to cause accidental ignition, and what fire hazards existed during shipment, storage, and use.

Frankly, we were amazed by test results which indicated a much higher level of safety than we had imagined. These tests are repeatable, if incredible. The scientific nature of the tests is such that they can be repeated with identical results by interested individuals and organizations. MPC does not recommend that its model rocket products be handled or mis-used in the fashion we have illustrated in these tests, and such testing should always be carried out with proper safeguards for persons and property only by those officials interested in checking our results. These tests are NOT intended for public demonstration or for use in academic instruction. They were designed and conducted to enlighten us and public safety officials.

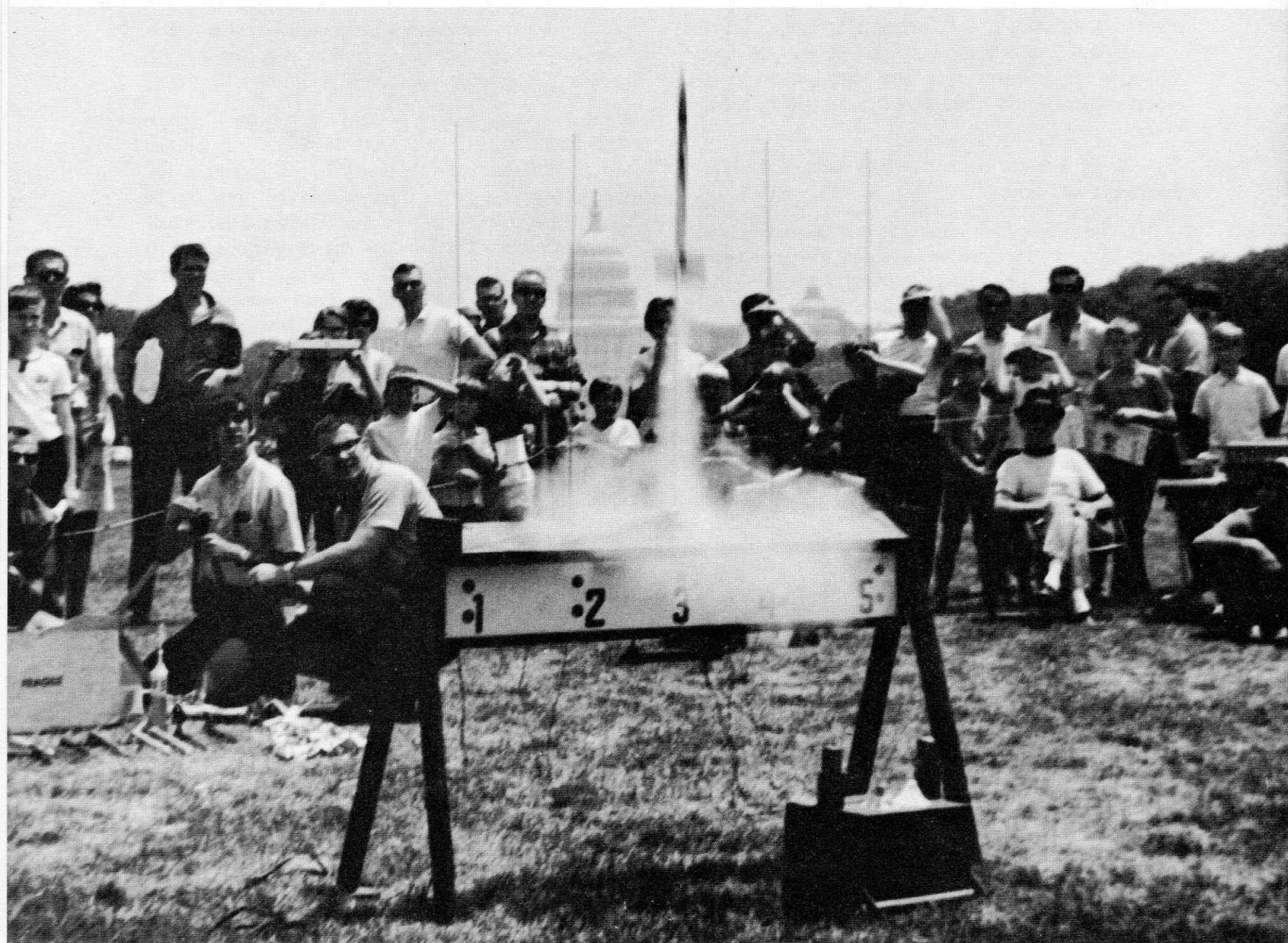
We invite comments, suggestions, and additional questions. If we do not have the additional information you want, we will do our best to get it.



PART ONE

Section 1:

the How and Why of MODEL ROCKETRY



WHAT IS MODEL ROCKETRY?

Model rocketry is:

- (a) an international aerospace sport;
- (b) a Space Age educational tool;
- (c) a "technological recreation" or scientific hobby.

WHO SAYS SO?

The National Aeronautics and Space Administration (NASA)

The United States Air Force (USAF)

The Federation Aeronautique Internationale (FAI)

The National Fire Protection Association (NFPA)

The American Institute of Aeronautics and Astronautics (AIAA)

The National Aeronautic Association (NAA)

The National Aerospace Education Council (NAEC)

The National Science Teachers Association (NSTA)

The Civil Air Patrol (CAP)



Model rocketry is model aeronautics brought into the Space Age with safe rocket power. Gary Jacobsen, 14, of New Canaan, Conn., prepares his rocket-boosted glider, an MPC FlatCat, for flight.

WHAT IS A MODEL ROCKET?

A model rocket is an aerospace model with the following specifications:

1. It is made of paper, plastic, balsawood, and other non-metallic materials without any metal as a structural part.
2. It weighs less than 16 ounces and carries less than 4 ounces of rocket propellant in accordance with federal regulation.
3. It uses a factory-made, pre-loaded non-metallic solid propellant rocket reaction engine that is replaceable after each flight. This eliminates any hazard of mixing or handling of rocket propellant chemicals.
4. Its model rocket engine is ignited electrically from a distance of 10 feet or more using a battery and a launch controller with safety features meeting NAR-NFPA standards.
5. It contains a recovery device to lower it safely and gently back to the ground so that it can be flown again.

WHO SO-DEFINES A MODEL ROCKET?

- A. The Federal Aviation Agency, Civil Air Regulations Part 101, Subpart A, pp. 101.1 a.3.ii a through d.
- B. The Federation Aeronautique International, Sporting Code, Section 4b.
- C. The National Fire Protection Association, Code for Model Rocketry, NFPA No. 41-L.

IS A MODEL ROCKET A TOY?

A flying model rocket is a scientifically-designed educational model . . . not a toy! It is capable of attaining speeds up to 300 miles per hour. It should be used only as instructed, in accordance with all safety codes, and with care and respect.

HOW LONG DOES IT TAKE TO BUILD A MODEL ROCKET?

Some model rockets come as carefully-designed, ready-to-launch models requiring little or no skill on the part of the rocketeer; they can be launched within minutes by inserting a few small parts, clipping a model rocket engine in place, and placing the model on a launch pad. Simple model rocket kits can be assembled in 30 minutes. Complex scale models and advanced payload-carrying model rockets often take weeks or months to assemble.

WHAT IS THE MODEL ROCKET SYSTEM?

A complete model rocket system consists of a flying model rocket, a model rocket engine, a launch pad, an electric launch control system, an electrical igniter for the model rocket engine, and a 6-volt or 12-volt battery.

HOW DOES A MODEL ROCKET OPERATE?

Ignition of the model rocket engine is accomplished electrically by the rocketeer at a distance of 10 feet or more from the launch pad.

The launch pad provides support for the model during pre-flight operations and provides the initial guidance for the model as it begins its flight when the airspeed is too low for the fins to stabilize the model.

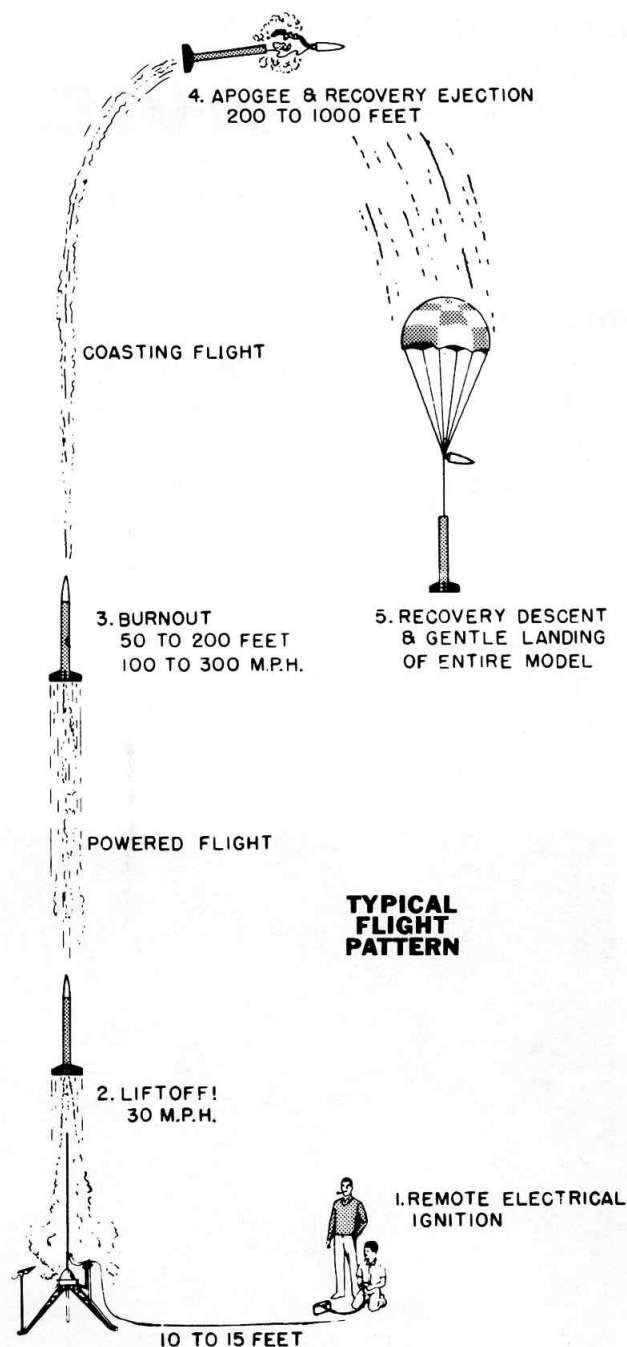
At the end of powered flight, the model rocket may be 50 to 500 feet in the air and moving at a speed of 100 to 300 miles per hour straight up. At that point, the engine's time delay charge activates automatically and permits the model to coast upward to peak altitude (apogee).

At or near apogee and a predetermined time after launch — pre-selected by the rocketeer in choosing the model rocket engine type for the flight — the recovery ejection charge in the model rocket engine activates. This produces a "retro-fire" puff of gas which pressurizes the inside of the body tube, forcing the recovery device forward to dislodge the nose cone. The recovery device then deploys, and the entire model returns to the ground gently under its parachute or streamer. Since all parts are tied together by various lines and cords, all pieces come down together in a gentle fashion so that the model can be prepared for another flight.

Another flight can be made almost at once by re-packing the recovery device and inserting a fresh model rocket engine and igniter in the model.

HOW DOES THE MODEL ROCKET ENGINE OPERATE?

The model rocket engine is started with an igniter that is operated electrically. When the firing button is pushed, electric current flows through the igniter wire, causing it to get hot. This heat passes to the solid propellant in the model rocket engine which in turn ignites. All combustion of the solid propellant takes place inside the engine casing and produces hot gas which rushes out of the specially-designed ceramic nozzle of the engine. This produces a propelling force that lifts the model off the launch pad and accelerates it skyward in an upward flight path. After the propellant has been used up, a delay charge of slower-burning propellant is automatically ignited, producing no thrust but allowing the model to coast upward, exchanging its speed for altitude. At a given number of seconds after liftoff — predetermined



by the modeller who chooses an engine with a pre-loaded time delay before launching — an ejection charge in the motor "retro-fires," producing a puff of gas that pressurizes the inside of the model, pushing the nose cone off and deploying the recovery device.

DO ALL MODEL ROCKETS OPERATE IN THE SAME MANNER?

While most model rockets operate in the same manner, there is a considerable difference in their performance. This is caused by differences in weight, sizes, and shapes of the model and the power of the model rocket engine used.

WHAT DOES A SIMPLE MODEL ROCKET CONSIST OF?

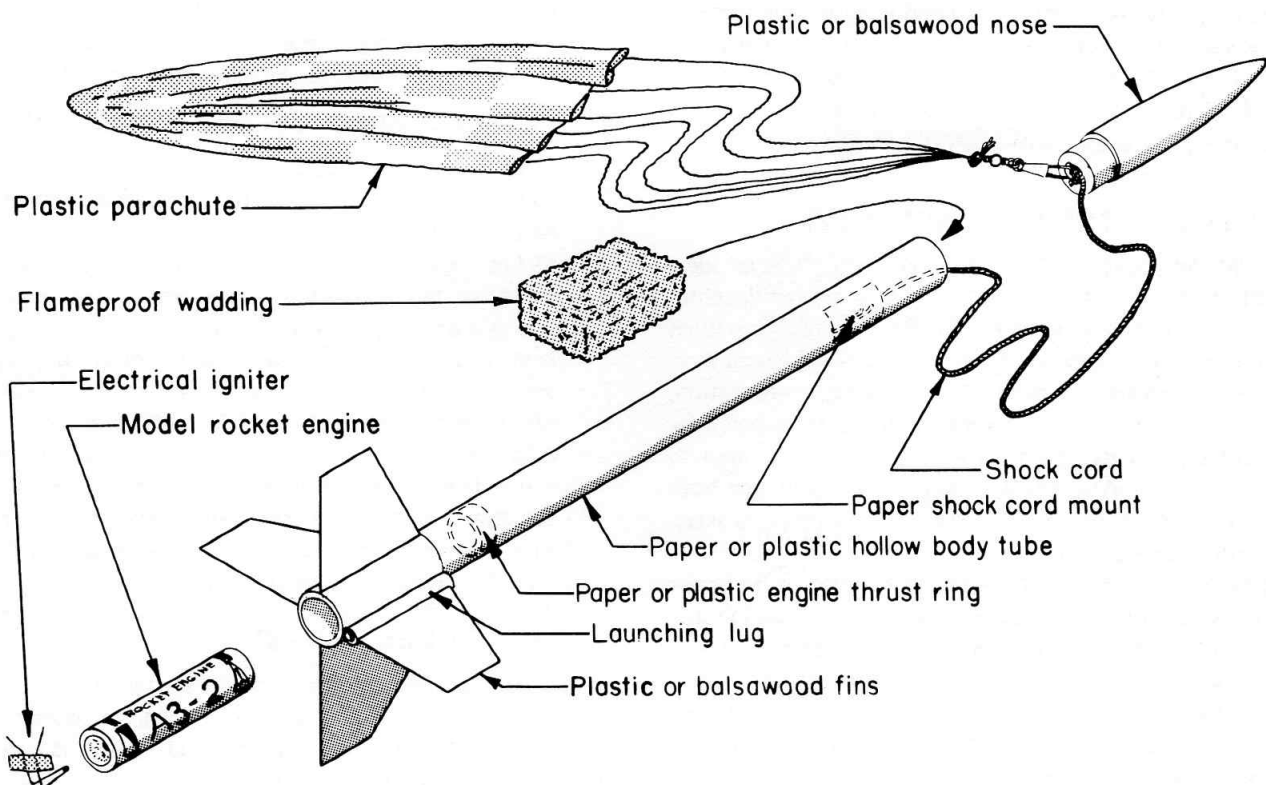
Most model rockets, regardless of their construction and performance differences, usually have the following components:

- a. A balsawood or plastic nose cone that can come off.
- b. A hollow, lightweight plastic or paper body tube that is the main structural airframe part.
- c. A launching lug which is a small tube on the side of the model which slips over the guide rod of the launch pad.
- d. A recovery device such as a plastic parachute or streamer that is packed inside the body tube and which is ejected forward by a "retro-fire" action of the model rocket engine at a predetermined time in the flight.
- e. A replaceable, expendable model rocket engine and its associated thrust mount and retainer.
- f. Fins which keep the model travelling in a true and predictable flight path like feathers on an arrow.
- g. Wadding to protect the recovery device from the retro-fire action of the engine and to help eject it from the model.
- h. An electrical igniter to start the model rocket engine.



HOW ARE MODELS RECOVERED?

The means by which a model rocket is recovered depends upon the design and construction of the model. The basic idea is to bring all parts of the model to the ground gently and safely so they can be used over and over again. Parachutes and streamers are used most frequently. However, tumble, drag, and glider devices can also be employed. If the rocket is designed to separate into two or more parts, recovery devices can be used on each part and packed within the model rocket body.





WHO ARE THE MODEL ROCKETEERS?

Rocketeers range in age from 11 to 70 with the median age being 15 years. They are people interested in the space age world of science and technology . . . and in a captivating hobby-sport that is a natural father-son activity. A recent study conducted in Pennsylvania indicates that the average I.Q. of model rocketeers is 141, that the model rocketeer is a good student and that model rocketry is a useful adjunct to academic studies of the physical and mathematical sciences.

IS IT A FATHER-SON ACTIVITY?

Model rocketry knows no age limits. It is an ideal father-son activity — and is even a mother-daughter activity in some families! Model rocketry combines modern technology and science, craftsmanship and shop practice, individual creativity and group co-operation, and the pursuit of excellence along with a healthful outdoor activity. Model rocketry is not confined to youngsters nor to NASA rocket experts, although both participate in the hobby. Printers, insurance brokers, photographers, artists, business executives, recreation directors, and school teachers are included in the roster of the millions of adult rocketeers in the United States. A father can use model rocketry to teach his children many things beyond the simple activity of putting together a model rocket kit and flying it. Sportsmanship, craftsmanship, self-reliance, discipline, and pragmatic approach are but a few of the things that can be learned with model rocketry as a tool.

HOW OLD SHOULD A MODEL ROCKETEER BE?

Experience indicates that youngsters less than 12 years old may have the enthusiasm but not the necessary manual skills to build a model rocket. However, if Daddy takes a major, active role in the construction and flying, children less than 12 can profit scholastically from the learning experience of model rocketry.

IS ADULT SUPERVISION NECESSARY?

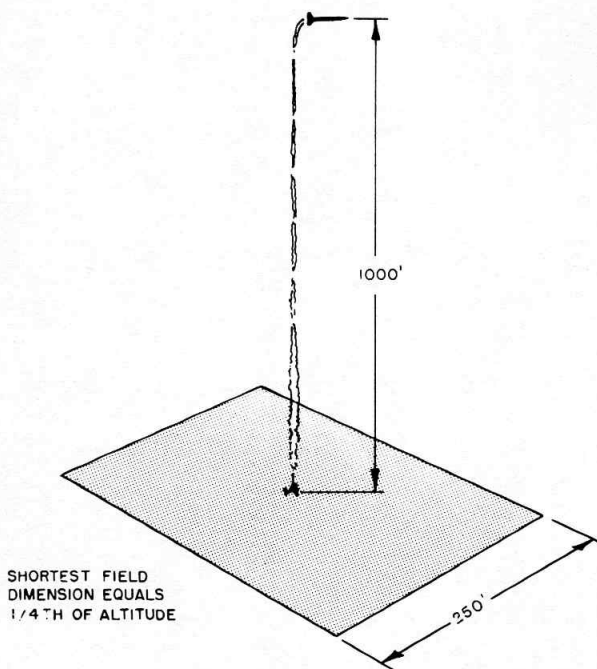
We recommend adult supervision in the construction and flying of model rockets because a young rocketeer's natural enthusiasm and excitement over flying a model rocket could cause him to overlook some important point in the count-down sequence. Although many young people are perfectly capable of building and launching model rockets safely, as the record has shown, the "double-check" feature of adult supervision can often prevent mistakes made in haste and excitement. And, to be quite honest, the presence of a responsible adult does a great deal to dispel the concern that is sometimes felt by others — often unwarranted, to be sure — who are not familiar with the excellent safety record of this form of youth rocketry.

WHAT DOES IT COST?

A complete model rocket "starter set" including model rocket kit, model rocket engines, launch pad, electric launch control system, and igniters is available in a single package for less than \$10.00. Components may also be purchased separately.

IS MODEL ROCKETRY DANGEROUS?

On the basis of experience, model rocketry is not dangerous if carried on in accordance with established and tested safety rules . . . just like any other human activity! Millions of model rockets have been flown safely. The most serious accidents to date have been several burned fingers caused by FAILURE TO READ AND FOLLOW INSTRUCTIONS AND SAFETY RULES. On the basis of the established record since 1957, model rocketry is safer than swimming, boating, baseball, and several other hobbies and sports. However, if model rocket equipment is mis-used, it can be dangerous . . . but a baseball bat can be turned into a lethal club, too. At this time, model rocketry is perhaps the safest of all hobbies except stamp collecting.



HOW MUCH SPACE IS REQUIRED FOR FLIGHT?

For most MPC model rockets propelled by Type A through Type C engines, a ground area the size of a football field is usually adequate. To calculate the size of field needed, divide the expected altitude of the model rocket by 4, the launch field should have no dimension shorter than this number. The area should be free of trees and power lines, and away from major highways and multi-story buildings.

ARE MODEL ROCKETS A HAZARD TO AIRCRAFT?

Normally, no. Most model rockets operate up to altitudes of 1500 feet. An aircraft below this altitude is probably there contrary to the Civil Air Regulations, depending upon where the flying area is located with respect to airports. The Department of Defense has had to create very expensive and highly sophisticated multi-million-dollar guided missiles in order to deliberately hit an airplane; the chances of a model rocket hitting an airplane in such a way as to cause serious damage are quite remote. Planes actually face a greater hazard from birds in flight. We do not recommend that model rocketeers establish flight areas in the approach lanes of airports where airplanes are taking off and landing; the pilot of a plane taking off and landing has plenty to do without worrying about model rockets. We have actually witnessed the collision between an aircraft and a model rocket which occurred at the Ninth National Model Rocket Championships held at the Mankato, Minn. airport. A model rocket flew into the path of a Cessna 150, a light single-engine private plane, while the plane was taking off. The model rocket went through the propeller and disintegrated into a cloud of balsa and paper confetti. The aircraft was not harmed.

WHAT IS MPC DOING ABOUT SAFETY?

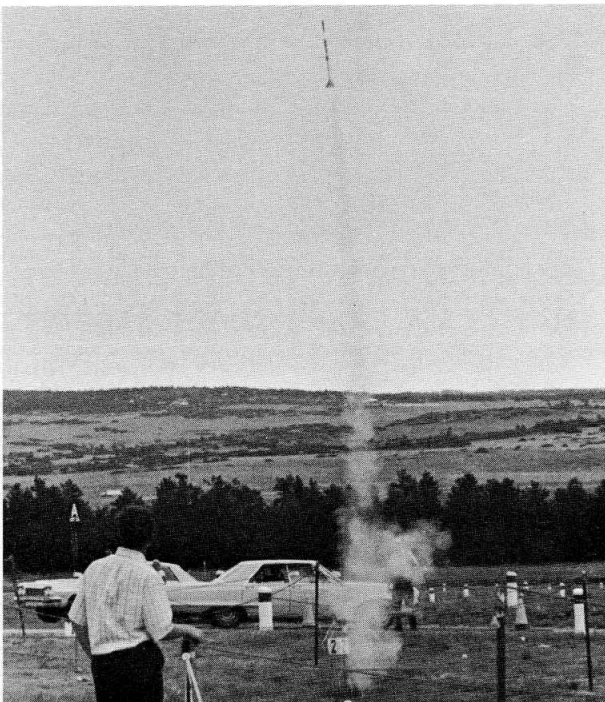
MPC has a lot of time and effort invested in its model rocket program; in addition, it has a social responsibility to produce safe products. Therefore, MPC is as interested in the safe design, operation, and use of its model rocket products as any concerned citizen, customer, or public safety official.

MPC has done and will continue to do the following things to promote model rocket safety:

1. A copy of the NAR-HIAA Model Rocket Safety Code is enclosed in each MPC model rocket kit.
2. Complete instructions for assembly and use are included in every MPC model rocket kit and with every sealed package of MPC model rocket engines.
3. All MPC products meet or exceed the standards established by the NAR and called forth in NFPA No. 41-L, Code for Model Rocketry.
4. All MPC publications on model rocketry stress safety and the scientific approach to model rocketry.
5. MPC maintains and continues to establish co-operative liaison with public safety officials at all levels of government.

DO THE RUSSIANS HAVE MODEL ROCKETS?

Yes, and there are some 5,000 model rocket clubs in the USSR organized as part of their Young Pioneers movement. The Russians are using model rocketry to help train their scientists and engineers. Other countries have model rockets, too — Sweden, Belgium, Germany, Czechoslovakia, Yugoslavia, Hungary, Bulgaria, and Canada are a few of the nations which have model rocketry, model rocket clubs, and model rocket competition. World Championships and international competitions are held regularly under the auspices of the Federation Aeronautique Internationale.



An MPC "Redstone-Quasar" lifts off at the 11th National Model Rocket Championships at the Air Force Academy in Colorado.

WHEN DID MODEL ROCKETRY START?

Model rocketry was born with the Space Age in 1957. Since that time, nearly 25,000,000 model rockets have been flown in the United States. 1957 also saw the start of the National Association of Rocketry (NAR), a non-profit educational and charitable organization formed for the purpose of guiding and encouraging the healthy and safe growth of model rocketry throughout the United States.

WHAT IS THE NATIONAL ASSOCIATION OF ROCKETRY?

The National Association of Rocketry (NAR) is part of the National Aeronautic Association and is the primary United States' organization for model rocketry. The NAR has a membership of several thousand serious model rocketeers of all ages, most of them organized in local chartered clubs. NAR membership is reasonable in cost and includes coverage under a \$300,000 liability insurance policy, a subscription to "Model Rocketry Magazine," a sporting license which permits you to enter and fly in national and international competition, and a book of contest rules.

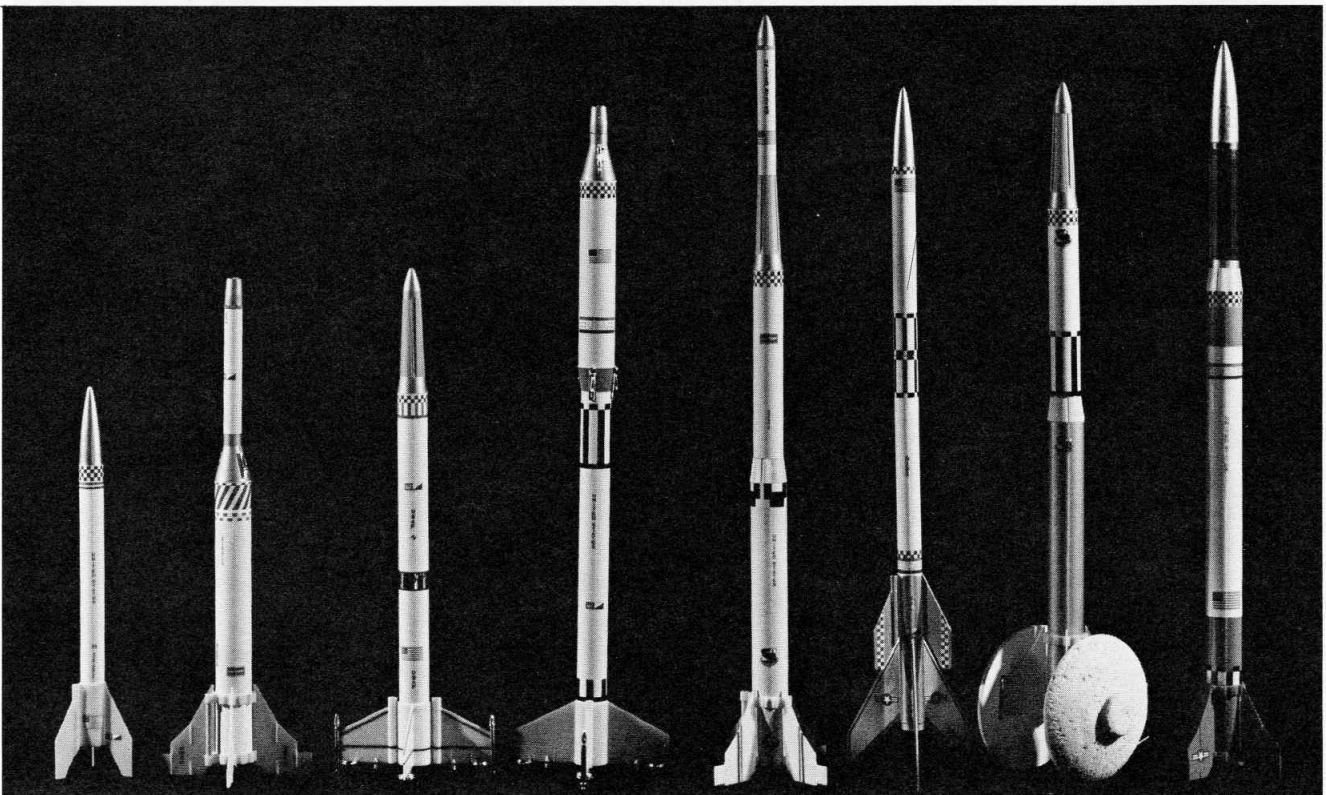
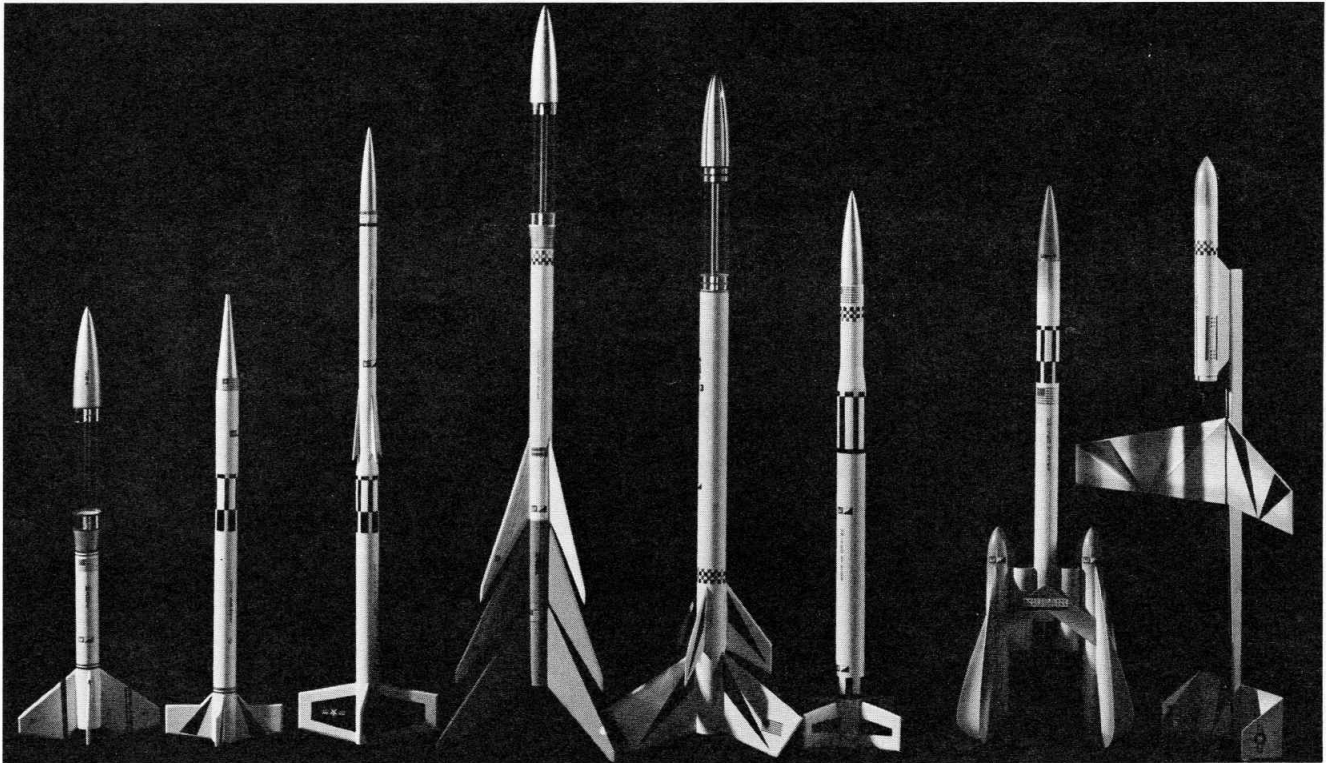
The NAR works directly with model rocket manufacturers to insure that model rocket products measure up to the stiff requirements of the joint NAR-NFPA standards. NAR tests and certifies model rocket engines.

The NAR also certifies United States model rocket performance records and acts as liaison between a model rocketeer and the FAI in Paris for international records. The first World Class FAI model rocket records were established by American model rocketeers.

Many government organizations have sought the help of the NAR with regard to model rocketry as it affects them. These include the Federal Aviation Agency, the Department of Health, Education and Welfare, the Food & Drug Administration, the Treasury Department, the Department of Defense, and NASA.

Further information on the NAR can be obtained from its headquarters, P.O. Box 176, McLean, Va. 22101.

Model Rockets come in many shapes and sizes to challenge the craftsmanship of young people, while at the same time teaching them manual, mental, and social skills valuable in our technological civilization. The largest model in these photos is about 24 inches high, and weighs less than two ounces. These examples were built from MPC Model Rocket Kits to indicate the wide scope of the hobby.



PART ONE

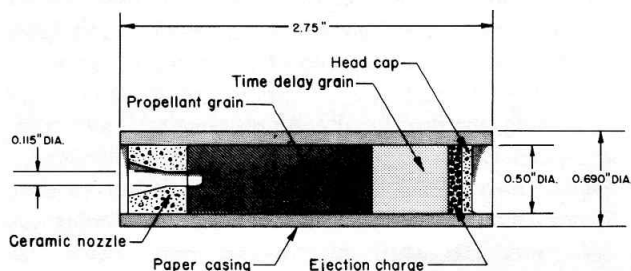
Section 2:

the How and Why of



WHAT IS A MODEL ROCKET ENGINE?

A model rocket engine is a miniature reaction engine designed and manufactured for the purpose of propelling a model rocket through the air and activating its recovery device. It is technically a solid-propellant reaction engine.



THE MPC MODEL ROCKET ENGINE

WHAT'S IN IT?

Refer to the cutaway drawing.

This shows an MPC Type C6-4 model rocket engine as though it were cut lengthwise down the middle to reveal the interior portions.

The casing is fabricated from tightly-wound paper and has very closely-controlled dimensions. Paper is used because it is strong and does not conduct heat easily.

The nozzle is formed of ceramic pressed into place and formed into a "deLaval" convergent-divergent nozzle of carefully designed size and shape. The nozzle is locked to the casing by deliberate physical distortion of the casing during manufacture of the engine.

The propellant is a solid piece of material with controlled burning characteristics dictated by its shape, density, and composition. Further details are to be found in the Appendix dealing with the internal ballistics of the model rocket engine.

The time delay is a piece of slower-burning propellant material.

The ejection charge consists of approximately 0.3 grams (5 grains) of FFFg black powder, less than in a .22-short shell, which acts as a pressurizing medium to eject the recovery device.

The ejection charge is held in place either with a paper cap fabricated of tag board or by a thin layer of ceramic.

HOW DOES IT WORK?

A special electrical igniter consisting of a piece of #33AWG nichrome wire coated at its tip with a bead of squib material is inserted into the nozzle and retained in place by tape. When an electric current of no less than 0.75 amperes at 2.0 volts passes through this wire igniter, it glows with resistance heat like an electric heater. When a temperature of 550° F is reached at the propellant surface in the nozzle, the propellant ignites and burns.

The propellant burns only on its surface from the aft end of the engine forward in the manner of a cigarette. In fact, this rocket propellant geometry is called a "cigarette-burning grain." All combustion takes place inside the casing. The propellant burns with a temperature of about 1090° F at a pressure of 106 pounds per square inch, producing about 2000 cubic inches of gas for each ounce of propellant burned. This gas rushes out the ceramic nozzle, its temperature and pressure declining as it does so. As the gas leaves the nozzle, it is at atmospheric pressure, has a temperature of about 600° F, and is moving at a speed of 2650 feet per second (about 1810 miles per hour). This rearward-rushing gas produces the thrust which propels a model rocket through the air. Because the amount of propellant area that is burning at any given instant can be closely controlled, the instantaneous thrust of the engine can also be controlled and pre-tailored to the requirements of model rocket flight.

Once the propellant is exhausted, the time delay charge is automatically activated. This produces no thrust and allows the model to coast upward. The time delay charge in MPC model rocket engines incorporates a chemical for the purpose of producing a smoke trail against the sky so that the model may be tracked to determine altitude.

When the time delay charge is exhausted a few seconds later, it automatically activates the ejection charge which produces a quick puff of gas to pressurize the inside of the model rocket airframe and thereby eject the recovery device.

When the model rocket is recovered, the expended engine casing is removed from the model and discarded. It is intended for only a single use.

CAN A USED ENGINE BE RE-LOADED?

No. It is intended for only a single use. Specific instructions are provided with each engine pack warning users not to re-load expended engine casings. The reason for this is, basically, that only experts should engage in the tricky business of handling raw rocket propellants and making rocket engines. This is why a model rocket engine is provided in a pre-loaded condition.

WHAT IS THE PROPELLANT?

The propellant is a dead-pressed, modified end-burning grain of composite solid propellant. The oxidizer is KNO_3 . The fuel and binder consists of C and S. Basically, it is a highly-refined modern version of black powder. The characteristics of this material as a solid rocket propellant are well-known and highly predictable. Its low energy content (specific impulse is only 80-85 seconds compared to values as high as 200-250 seconds for most solid rocket propellants) and its stability make it an ideal rocket propellant for use by non-professionals in factory-loaded engines. The success of this material as a model rocket propellant is witnessed by the 25,000,000 model rocket engines made and used with a high degree of safety over the past decade.

CAN THE PROPELLANT BE EASILY REMOVED?

Not easily, because the propellant is a solid chunk of material approximately 0.50" in diameter and less than an inch long. It is totally enclosed within a thick paper casing. It requires a very sharp knife and lots of patience to remove it. A fire marshal of a large New England city was once asked to try it, and he gave up after carving on the casing for five minutes. Yes, it is possible to remove the propellant, but it takes lots of effort. It is far easier to get the powder out of a shotgun shell. Furthermore, the model rocket propellant will not explode when removed from the casing; it just burns.

IS THE PROPELLANT SENSITIVE?

We pounded on engines with a hammer, and we couldn't get them to ignite or explode. We drove a car over some engines, and nothing happened. We even fired a 30-30 rifle into an engine at point-blank range, and it did not ignite or explode. We conclude from these tests that, under ordinary conditions of shipment, storage and use, a model rocket engine isn't going to spontaneously ignite or explode due to physical shock. It is about as sensitive as a Tootsie Roll.

IS THE PROPELLANT TOXIC?

It doesn't taste very good, in the first place. But you could probably eat a couple of engines with no ill effects. Carbon and sulfur are not toxic. KNO_3 is also known as saltpeter and has long been used in medicine. Saxe rates KNO_3 as "moderately toxic" and notes that "small repeated doses may lead to weakness, headache, general depression and mental impairment." Therefore, don't make a habit of eating model rocket engines.

WILL IT EXPLODE?

We tried our best to make model rocket engines explode by hitting them, throwing them in fires, shooting bullets into them, burning them with welding torches, and otherwise mis-treating them. We never did produce an explosion, although a model rocket engine will ignite and burn under very extreme conditions. The nature of the propellant is such that it does not detonate like a high explosive; in other words, it does not go "high order" where all of the propellant undergoes combustion within a couple of milliseconds. Occasionally, due to humidity conditions, mis-treatment, or tampering, the propellant grain becomes separated from the inner casing wall, thereby exposing additional propellant area to the combustion process; this, in turn, creates more burning area, which results in more gas being produced, which raises the internal pressure. This increased internal pressure usually dislodges the head cap and time delay from the casing, causing the engine to "blow through" in a forward direction, ejecting the nose cone and recovery device from the model. Under other conditions of increased internal pressure, the nozzle will be dislodged from the casing, ejecting to the rear in a cloud of ceramic dust. It is extremely unlikely that a condition could prevail that would cause rupture of the fiber engine casing which has been hydrostatically tested to an internal pressure of 1000 pounds per square inch (at which point the pressurizing fluid was seeping out through the pores in the fiber, making higher test pressures impossible to obtain).

DOES THE ENGINE CASING GET HOT?

The outside surface of the engine casing does not get hot enough to cause a burn. In fact, it could be held in the bare hands while operating, but we do not recommend or encourage this sort of activity. In some model rockets, the engine is retained and centered by parts made of polystyrene plastic which suffers heat distortion at temperatures between 165°F and 190°F ; these parts show no heat distortion after repeated flights, proving that the external temperature of the casing does not reach the plastic's softening temperature.

IS THE EXHAUST GAS TOXIC?

Not in the quantities produced by model rocket engines. Saxe lists as "slight toxicity" the ammonium carbonate solid residue, as "moderate toxicity" the potassium sulfite solid residue, and as "variable" the potassium sulfide and potassium sulfocyanate solid residues. Our recommendation: do not eat the exhaust residue from more than 10 exhaust deflectors.

DOES IT PRODUCE A FLAME WHEN OPERATING?

No. All combustion takes place inside the fiber casing. The jet exhaust produces a plume of luminous gas approximately 9 inches long. This glowing plume is caused by the high temperature of the exhaust gas and the luminous microscopic solid products of the internal combustion process. Basically, the exhaust plume is much like the glowing gas plume sometimes seen coming from the exhaust pipes of high-performance racing cars.

WHAT WILL THE EXHAUST JET DO?

We ran a series of tests to find out. The jet from an operating MPC Type A3-2 model rocket engine will not burn a hole through a single sheet of 20-pound white typewriter paper when the jet is directed perpendicularly against the paper at a distance of 12 inches. At a distance of 6 inches, the jet literally punches through the paper, leaving a hole about 1.25" in diameter that is self-extinguishing. We never did succeed in setting the paper on fire.

WILL THE JET CAUSE A BURN?

If your fingers are in the jet, they will get burned. This is why specific instructions are given for the use of remotely-controlled electric ignition of all MPC model rocket engines. If a person gets burned by a model rocket engine, you can bet that it happened because he was not following instructions; he was probably trying to ignite it with an open flame from a match in direct disregard of all safety rules, common sense, and instructions.

HOW DO YOU TREAT A BURN IF ONE HAPPENS?

Get the finger immersed in ice water or cold water as quickly as possible. See a physician. A tetanus shot is recommended to be on the safe side. The temperature of the exhaust is such that no bacteria or virus could exist in it, and none of the exhaust products is poisonous.

CAN YOU LIGHT IT WITH A MATCH?

We tried several ways of igniting a model rocket engine using an open flame. In all cases, the fiber casing caught fire and began to burn after 30-45 seconds, but in no case did the engine ignite. Had the engine been in a model rocket, the model rocket would have caught fire and burned first. Our conclusion is: Don't try to light it with a match because you will only set your model rocket on fire instead.

CAN MODEL ROCKET ENGINES BE IGNITED WITH A FUSE?

An ordinary Safety Fuse of the sort commonly used in fireworks will not fit into the nozzle of an MPC model rocket engines so that it interfaces with the propellant grain. It is very difficult and unreliable to attempt igniting model rocket engines with fuse. It is possible to ignite model rocket engines by using "Jetex wick" which is available in some hobby stores, but this practice is strongly discouraged by MPC and other model rocket manufacturers.

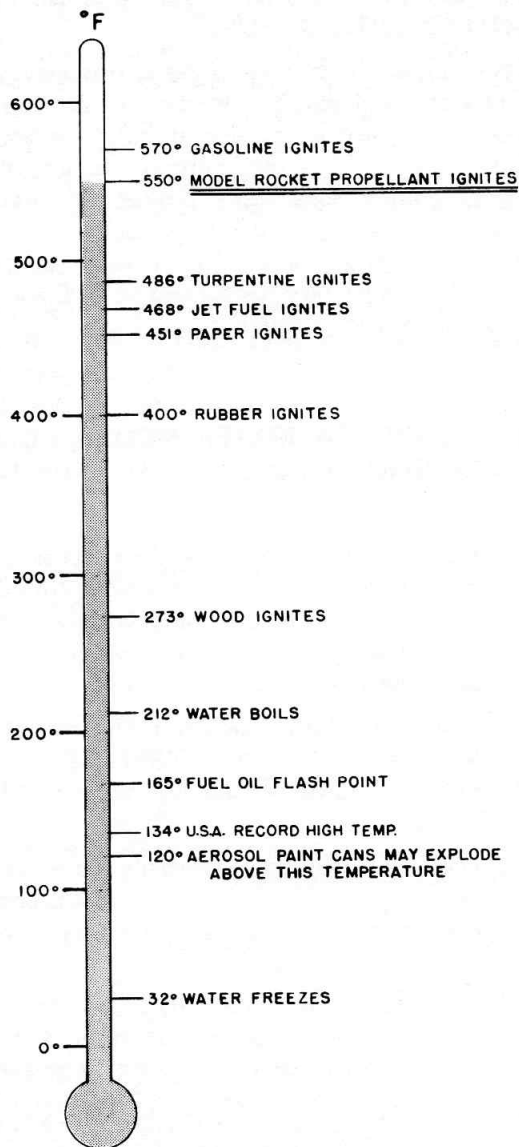
IS IT SAFE TO IGNITE MODEL ROCKET ENGINES WITH FUSE?

No. Reasons:

- a. Fuse ignition is unreliable. Some types of fuse will not ignite model rocket engines. With a fuse, it is possible to have a "hang fire" in which the fuse smolders in the nozzle, igniting the propellant randomly.
- b. Fuse ignition cannot be timed. Fuse burning rates are notoriously random, depending upon type of fuse, storage conditions, age, atmospheric humidity, etc.
- c. Upon ignition, glowing remnants of the fuse may be ejected from the nozzle, thereby falling into dry, ignitable material around the launcher and starting a grass fire.
- d. With fuse, there is no control over the instant of lift-off. During burning of the fuse, it could happen that a low-flying aircraft might appear, that a person unknowingly might approach the launcher or enter a hazardous area, or that the launcher might be blown over by a gust of wind. All of these conditions have occurred many times with model rockets, and the use of an electrical ignition system permitted the immediate and complete cessation of the firing procedure, returning the model to a safe condition.
- e. It is not safe to ignite a Saturn-V with a fuse, and when the professional rocketeers at Cape Kennedy start using fuses to light real rockets, we might consider it for model rocketry, which is astronautics in miniature.

UNDER WHAT CONDITIONS WILL A MODEL ROCKET ENGINE IGNITE?

Basically, this question is one of fire hazard. The results of the various fire immersion tests (see appendices) indicate that a model rocket engine will not undergo spontaneous ignition in a fire unless, literally,



"the barn is burning down already." A model rocket engine will ignite only if solid particles or an open flame with a temperature exceeding 550° F reaches the surface of the propellant itself. This can be caused by any fire which burns away a portion of the fiber engine casing to expose the propellant itself to the fire or by the insertion and activation of an electric model rocket igniter into the nozzle in accordance with instructions. The above two techniques were the only ones we found capable of igniting a model rocket engine.

Basically, this is because (a) the fiber engine casing is an excellent insulator, and (b) a bubble of insulating air is trapped in the nozzle and forward end, preventing hot particles or flame from getting into the engine casing by this most obvious and easy route to the propellant surface. In no case during our tests did an engine ignite because of flame or heat passing up the nozzle or into the forward end of the casing. In all

cases, spontaneous ignition in a fire was due to the fire burning away the engine casing to expose the propellant. The amount of time required to burn through the fiber casing is a function of the temperature and energy density of the flame, varying from 3 to 5 minutes in an intense wood-and-paper fire to about 30 seconds with an oxy-acetylene cutting torch.

We have evidence of the total destruction by fire of a hobby store in Darien, Connecticut, and the subsequent retrieval of all model rocket engines from the site with no ignition of the propellant evident.

ARE MODEL ROCKET ENGINES A FIRE HAZARD?

Certainly less so than other items openly available and sold in hobby and hardware stores — aerosol paint cans, model airplane fuel, model airplane glue, butyrate dopes in cans and bottles, acetone and other liquid plastic cements, and various solvents. They will certainly not cause a fire during shipment and storage, and they will not contribute to the activity of a fire in which they are involved. In common with many tools, sports equipment, and hobby items, they could start a fire if the exhaust jet were used as a torch . . . but the same holds true of the butane torch in a home workshop.

WHAT IS THE FIRE RECORD OF MODEL ROCKET ENGINES?

Model rocket engines have started no fires during shipment or storage, nor have they contributed to any fires. There have been incidents of grass fires being started through misuse of model rocket engines — i.e.: attempting to ignite a model rocket engine using a fuse, the fuse falling into dry grass, and the grass catching fire.

WILL MODEL ROCKET ENGINES CONTRIBUTE TO A FIRE?

Tests have indicated (see appendix 2) that a sustained fire of 3 to 5 minutes duration is required to burn through the outer paper engine casing and ignite the propellant. We were unable to ignite the engines with a superficial fire. Under the extreme conditions necessary to cause spontaneous ignition of MPC model rocket engines, and due to their non-propulsive nature once ignited by a sustained fire, it is quite unlikely that model rocket engines would contribute greatly to the sort of fire which, having been in progress for 3 to 5 minutes, would be capable of igniting the engines.

HOW ARE MODEL ROCKET ENGINES SHIPPED?

Model rocket engines may be sent by bus, train, ship, and air with no special containers under D.O.T. shipping regulations for I.C.C. Class C Toy Propellant Devices.

CAN MODEL ROCKET ENGINES BE MAILED?

YES. Since 1958, model rocket engines have had permission from the U.S. Post Office Department for shipment by both regular Parcel Post and by Air Parcel Post. At the present time, up to 27 model rocket engines can be shipped in a single package. There have been no incidents of fire or explosion with model rocket engines sent by mail and it is estimated that nearly 10 million model rocket engines have been safely sent through the mails.

WHERE ARE MODEL ROCKET ENGINES SOLD?

The majority of model rocket engines are sold in specialty stores such as hobby shops or in the hobby departments of department stores. They are also sold in bicycle shops and model raceway centers. Model rocket engines are also sold by mail order because of the ability to mail them.

ARE MODEL ROCKET ENGINES SOLD INDISCRIMINATELY?

In nearly all specialty shops and the majority of stores where model rocket engines are sold, considerable discretion has been exercised in the sale. Generally, the history of model rocket engine sales has been safe. This is because the Hobby Industry Association of America (HIAA) has a strong educational program of mailings, publications, magazine articles in trade publications, and other continuing projects designed to acquaint hobby dealers and their employees with the commonsense safety aspects of model rocket engine sales. In addition, MPC conducts a strong program of mailings and briefings of their own salesmen and the salesmen of hobby wholesalers. Therefore, the majority of retail outlets for model rocket engines have generally shown a remarkable history of discretion in sales. For example, some hobby store owners ask youngsters to come in with their parents when buying model rocket engines until the store owner gets to know the youngster and begins to learn whether or not the young modeler uses the engines properly and safely.

ARE MODEL ROCKET ENGINES FIREWORKS?

They are "I.C.C. Class C Toy Propellant Devices" according to tests conducted by the Bureau of Explosives of the Association of American Railroads under the provisions of I.C.C. Tariff No. 23, paragraph 173.100(u). Special fireworks and common fireworks are different classifications according to the I.C.C. and the Department of Transportation. This I.C.C. tariff is also the same tariff of 34 States.

A model rocket engine is not intended to "produce a display of light or sound" which is the usual definition applied to fireworks. A model rocket engine is a propulsion device for models.

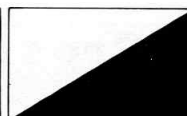
The National Fire Protection Association has recognized this differentiation between fireworks and model rocket engines. It has a separate code (NFPA No. 494) for fireworks and for model rockets (NFPA No. 41-L).

The only point of commonality between the sky rocket firework and the model rocket engine is the fact that they both operate by virtue of Newton's Third Law of Motion.

A model rocket bears a much closer technical relationship to such solid-propellant space launch vehicles as the NASA Scout and the USAF Titan-IIIC . . . which are far beyond the common sky rocket in their reliability and technical content.

Some officials have stretched the interpretation of local and state fireworks laws — which are rightly designed to protect the public — to include model rockets. This is usually the result of lack of knowledge about model rocketry. Frankly, one of the purposes of this booklet is to provide the information necessary for such public safety officials to make intelligent, informed decisions on such matters.

A large number of states and localities have either exempted model rocketry from their fireworks laws or have passed specific permissive legislation establishing model rocketry in an entirely different, less restrictive category. MPC maintains current information on the status of model rocketry in various parts of the country. If there is a question in your mind concerning this point, please contact MPC.



**MODEL
PRODUCTS
CORPORATION**
Mount Clemens, Mich. 48043

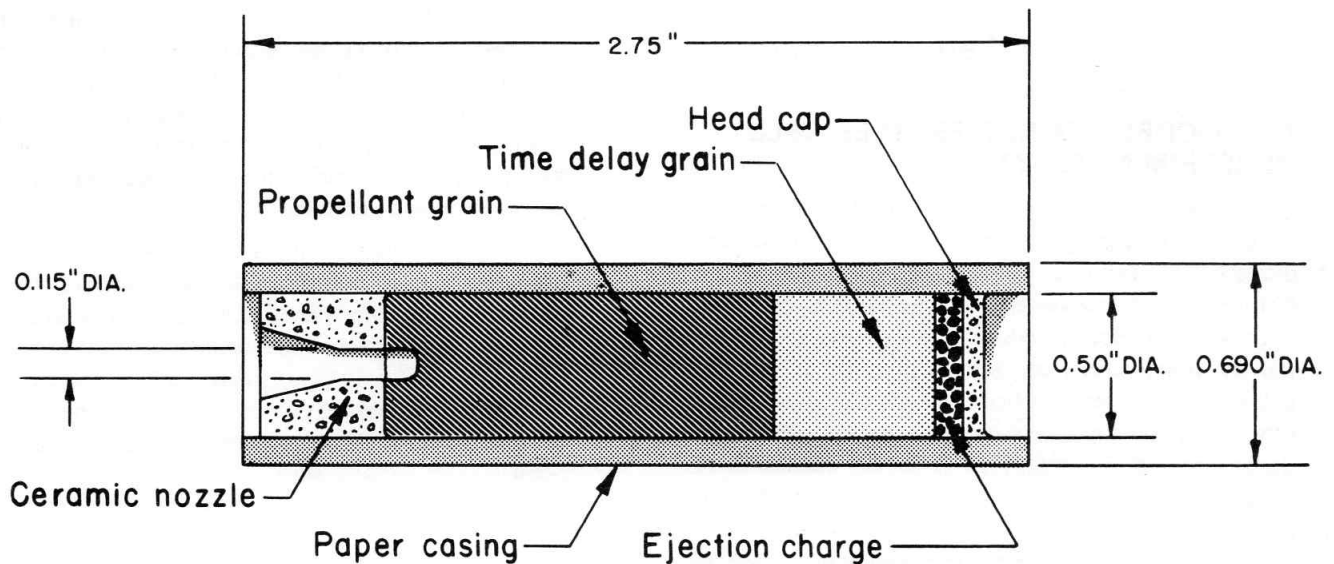
PART TWO

Appendix 1:

THE MPC MODEL ROCKET

ENGINE

A. DIAGRAM:

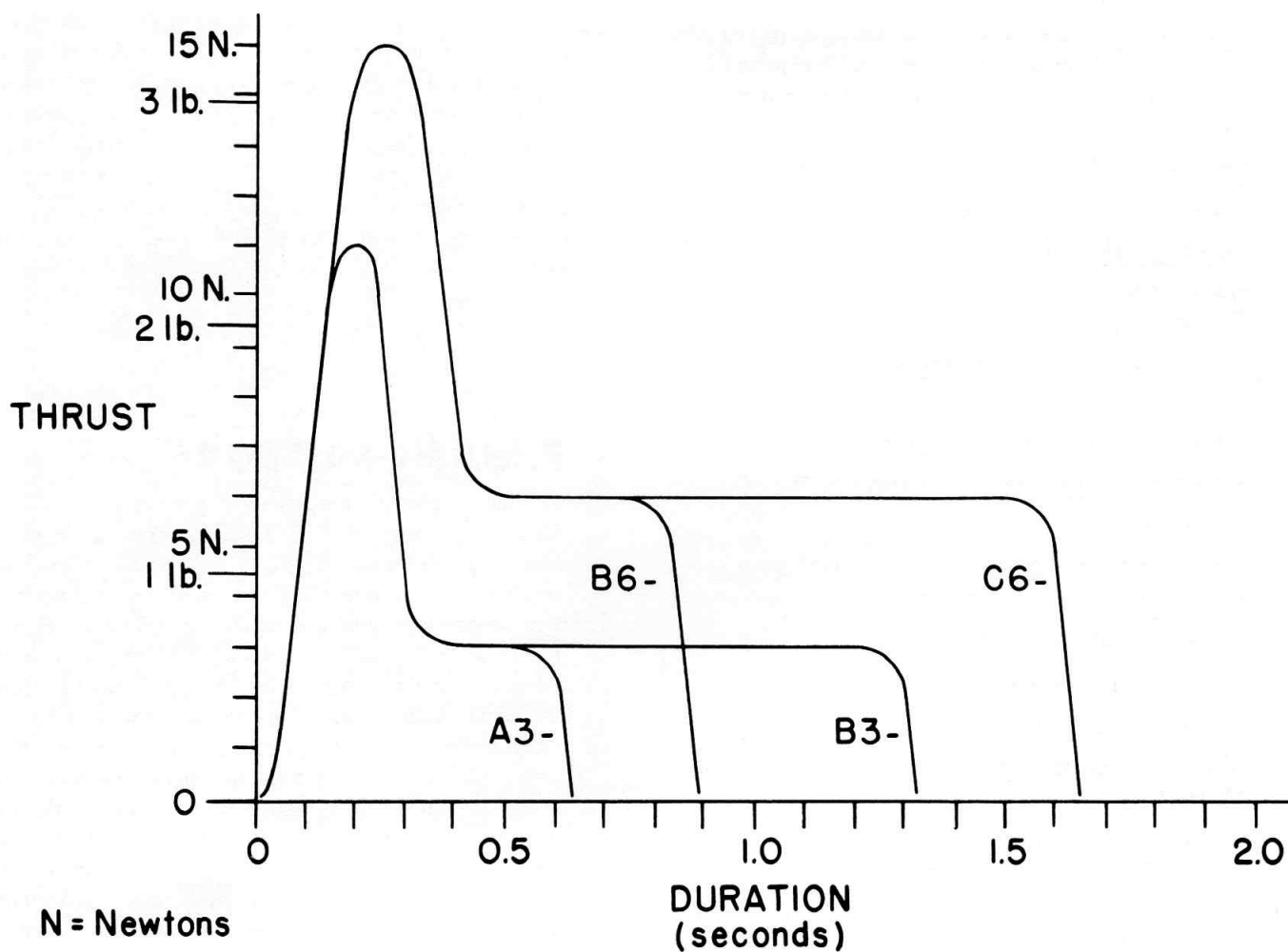


Cross-section, Type C6-4

B. PERFORMANCE CHART:

NAR TYPE =	A3-2	B3-3	B6-0	B6-4	C6-0	C6-4
Length (inches)	2.75	2.75	2.75	2.75	2.75	2.75
O.D. (inches)	0.690	0.690	0.690	0.690	0.690	0.690
I.D. (inches)	0.406	0.406	0.500	0.500	0.500	0.500
Nozzle diameter (inches)	0.104	0.104	0.115	0.115	0.115	0.115
Propellant wt. (grams)	3.20	5.50	6.00	6.00	11.00	11.00
Delay wt. (grams)	0.60	0.80	0	0.12	0	0.12
Total wt. (grams)	18.0	20.4	16.9	19.6	19.9	22.6
Total impulse (newton-sec.)	2.39	4.75	4.75	4.75	9.50	9.50
Max. thrust (newtons)	11	11	15	15	15	15
Average thrust (newtons)	3.4	3.4	6.0	6.0	6.09	6.09
Duration (sec.)	0.63	1.32	0.90	0.90	1.64	1.64
Time delay (sec.)	2	3	0	4	0	4

C. THRUST vs. TIME CURVES:



D. INTERNAL BALLISTICS

(Data was determined with the assumptions that the combustion process is adiabatic and isentropic, is in frozen equilibrium, and is complete. It is also assumed that the nozzle exit pressure is 14.7 pounds per square inch absolute. The exhaust products were assumed to behave as an ideal gas because the solid particles in the exhaust are assumed to be less than 0.0001 inches in diameter and thus have no effect on the thermodynamic properties of the exhaust gas. Insofar as is possible, calculated results have been checked against measured test results with excellent agreement well within measurement tolerances.)

Model Rocket Engine Type: MPC Type C6-4 cored/end-burning solid propellant model reaction engine intended for the propulsion of aeromodels. (This type chosen because it is the largest current engine produced by MPC.)

Propellant: Composite solid propellant consisting of 74% KNO_3 as an oxidizer and a combination of 15.6% C and 10.4% S as fuel-plus-binder. All percentages by weight.

Delivered specific impulse (I_{sp}): 82 $\text{lb}_f\text{-sec}/\text{lb}_m$

Exhaust velocity: 2650 ft/sec

Molecular weight of exhaust gas: 34.75 lb_m/mole

Gas constant (R) of exhaust: 44.5 $\text{ft}\cdot\text{lb}_f/\text{mole}\cdot\text{degree Rankine}$

Ratio of specific heats of exhaust: $k = 1.29$

Nozzle area ratio: 1.75

Propellant density: 0.067 lb_m/in^3

Propellant burning rate: 1.15 in/sec

Burning area ratio: 19.7

Volume of exhaust gasses at STP: 285 cm^3/gm

Chamber temperature: 1550° R

Throat temperature: 1355° R

Exit nozzle temperature: 1000° R

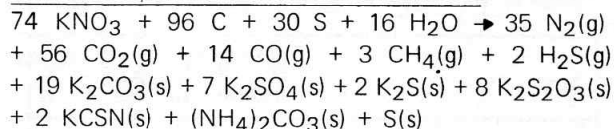
Chamber pressure: 106 psia

Reaction products of propellant: 43% gas, 56% solid, 1% H_2O

Gaseous exhaust products by volume: 30.6% N_2 ; 49.2% CO_2 ; 2.6% CH_4 ; 1.8% H_2S ; 3.5% H_2

Solid exhaust products by weight: 44.4% K_2CO_3 ; 20.5% K_2SO_4 ; 25.8% $\text{K}_2\text{S}_2\text{O}_3$; 3.7% K_2S ; 0.5% S; 3.3% KCSN; 1.6% $(\text{NH}_4)_2\text{CO}_3$; 0.2% C

Chemical equation of combustion reaction:



Toxicity of propellant: Rated 0 – 1 (Saxe)

Toxicity of exhaust products: Rated 0 to 2 in amounts produced by single engine.

Peak thrust: 15 Newtons (3.37 lb_f) at 0.020 sec. after ignition.

Sustainer thrust: 6 Newtons (1.35 lb_f)

Duration: 1.64 seconds

Propellant weight: 11.00 grams (0.388 oz_m)

Delivered total impulse: 9.50 Newton-seconds (2.14 $\text{lb}_f\text{-sec}$) (3-sigma value with 99% confidence level in each lot of 100 engines.)

E. STANDARDS

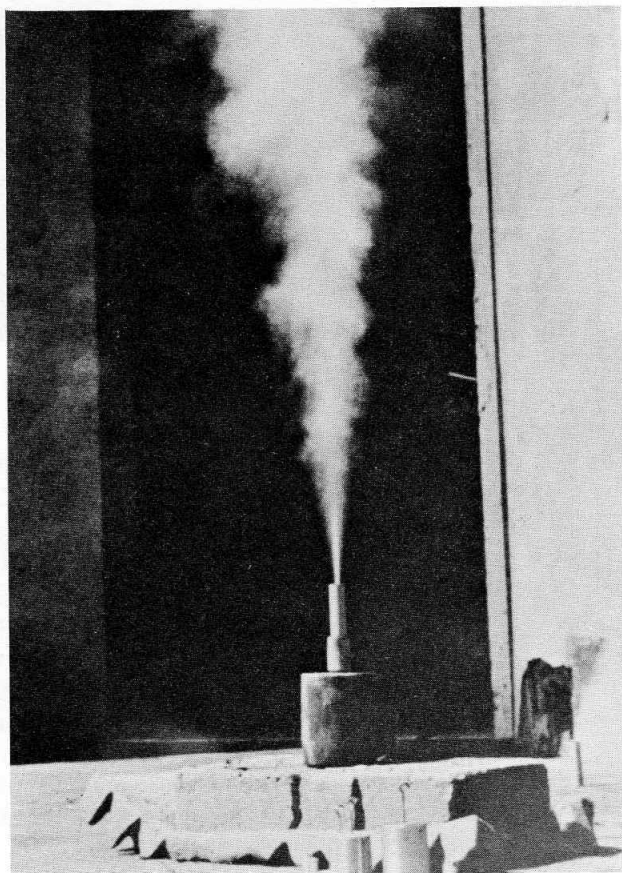
All MPC model rocket engines are manufactured in strict accordance with international and national standards jointly developed by the Federation Aeronautique Internationale (Section 4b, FAI Sporting Code), the National Association of Rocketry, the Hobby Industry Association of America, and the National Fire Protection Association (NFPA No. 41-L). MPC model rocket engines also meet all standards established for I.C.C. Class C Toy Propellant Devices (I.C.C. Tariff No. 23 para. 173.100(u).)

F. MANUFACTURE

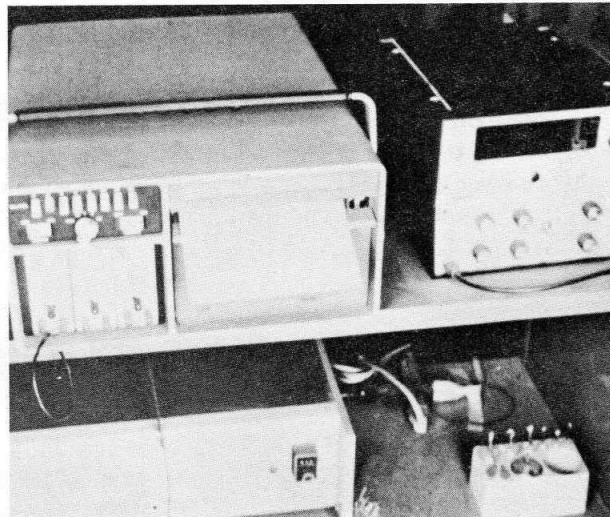
MPC model rocket engines are manufactured in Madison, Wisconsin, under the direct supervision of Myron D. Bergenske, B.S., M.S. Fabrication takes place on fully automated machinery capable of producing thousands of identical model rocket engines each hour. Incoming raw materials are carefully checked for conformance to rigid specifications. Technicians then load the paper casings, powdered ceramic, powdered propellant, pelleted time delay charges, ejection charge mixture, and head cap mixture into an engine machine. The production machinery is operated by pneumatic and hydraulic pressure. Nozzle, propellant, and time delay are dead-pressed into the fiber casing. The propellant grain thus becomes a homogeneous rocket propellant grain with controlled burning characteristics. Some of the processes used in the fabrication of a model rocket engine are proprietary.

G. TESTING

Following manufacture, each engine lot of 100 engines is physically inspected and 4 random samples are removed. The first of these random samples of "green" engines is static tested to determine the nature of its thrust-time curve, its total impulse, its duration, and other performance parameters. The static test stand consists of a BLH SR-4 strain gage load cell with suitable bridge power supply and signal conditioner, coupled to a Midwestern light-beam oscillograph and an electronic integrator. After several days of "curing" or "aging" in which internal stresses are brought to equilibrium, the second engine is static tested. If all quality control tests are passed, the engine lot is released for packaging and shipment. Engine lots are dated with the day of manufacture, and the two remaining quality control engine samples are retained for any needed future testing of that production lot.



Static test of a production Type C6-4 model rocket engine at MPC's engine manufacturing facility, Madison, Wisconsin. Engine is set nozzle-up in a fixture atop a B-L-H SR-4 strain gage load cell which measures thrust force. Note calibrating weights in foreground. Note rapid dissipation of jet exhaust by turbulent mixing.



The electronic test equipment used by MPC at their engine manufacturing facility, Madison, Wisconsin. This equipment consists of bridge amplifiers for the strain gage load cell, digital integrators to provide direct read-out of engine total impulse, and light beam oscillograph chart recorder for recording the thrust vs. time characteristics of the test engine.

H. CERTIFICATION

Classed as "I.C.C. Class C Toy Propellant Device" under provisions of paragraph 173,100(u) of I.C.C. Tariff No. 23 by test of Bureau of Explosives, Association of American Railroads.

Classed as "Contest Certified" and "Safety Certified" by the Standards and Testing Committee, National Association of Rocketry, an affiliate of the National Aeronautic Association, United States Representative to the Federation Aeronautique Internationale. This further certifies that they meet all standards of the Federation Aeronautique Internationale, the National Association of Rocketry, and the provisions of the Code for Model Rocketry NFPA No. 41-L of the National Fire Protection Association. By virtue of this certification, they may be legally sold in the States of Massachusetts, Connecticut, New Jersey, Pennsylvania, and Maryland.

Classed as "Model Rocket Engine," certification No. M2-82, State of California.

PART TWO

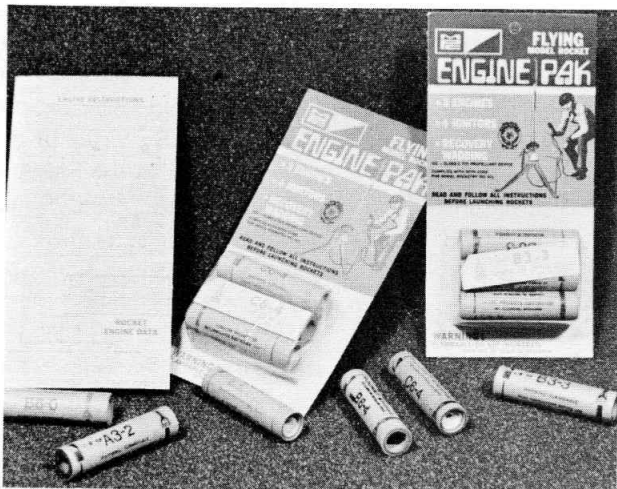
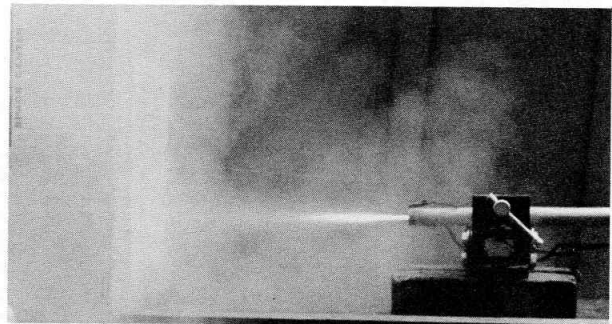
Appendix 2

MODEL ROCKET ENGINE

SAFETY TESTS

Introduction:

The Model Rocket Engine Safety Tests conducted and reported herein were designed to determine what hazards, if any, existed in the shipment, storage, handling and use of model rocket engines. We attempted to duplicate under test conditions those operations and exposures which, in real life, would be the concern of safety officials.



MPC model rocket engines showing packaging.

The tests were designed, conducted, monitored, and photographed by G. Harry Stine, a consultant to MPC and a Member of the Pyrotechnics Committee of the National Fire Protection Association, and Myron D. Bergenske of MPC who is in charge of the design, development, and production of the MPC model rocket engines. The tests were conducted in May 1970 in Madison, Wisconsin, and New Canaan, Connecticut. Production model rocket engines were used. No attempt has been made to "massage" the test data in any way to make it more attractive and positive. Every attempt has been made to include ALL the data, and not just selected data.

A. Hammer Blow Test:

Purpose: To determine if a model rocket engine could be ignited by a physical blow or shock.

Procedure: An MPC Type B3-3 model rocket engine was placed upon a concrete floor and struck vigorously with a 16-ounce claw hammer.

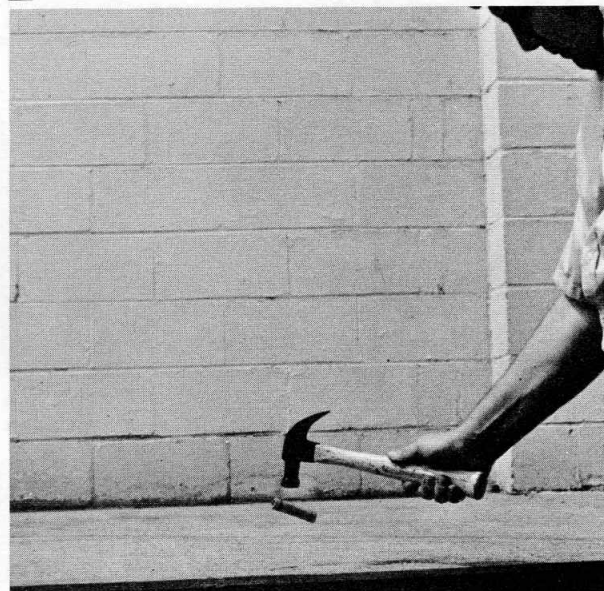
Results: No ignition occurred. Three tests were conducted. In each test, a single blow of the hammer distorted and flattened the paper engine casing and destroyed the ceramic nozzle, rendering the engine useless.

1



Hammer blow test. Mike Bergenske prepares to wallop an MPC Type B3-3 model rocket engine with a hammer.

2



Impact! Note the model rocket engine bouncing from the force of the hammer blow.

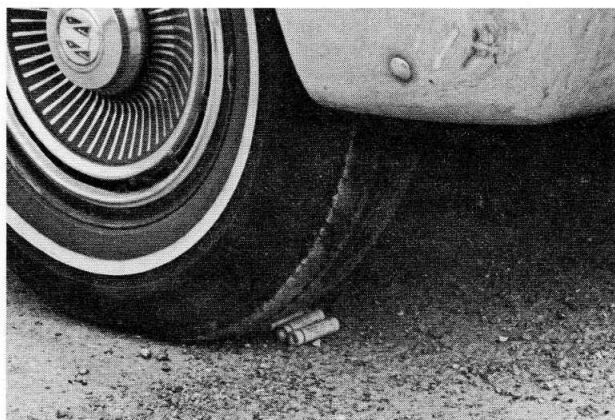
3



The impact of the hammer blow completely destroys an MPC model rocket engine but does not cause it to ignite or explode.

B. Automobile Crushing Test:

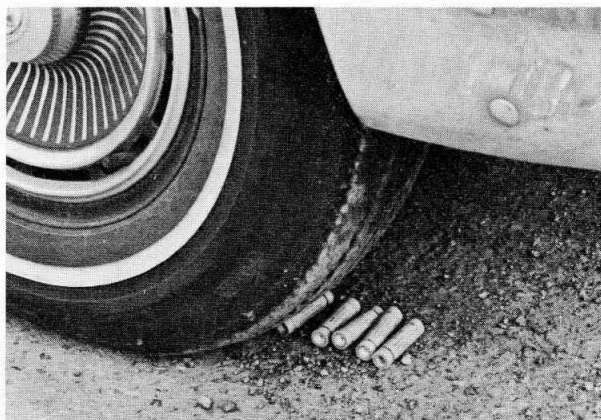
Purpose: To determine whether or not a model rocket engine would ignite or explode if subjected to the crushing force of an automobile driving over it, and, if no ignition or explosion took place, whether or not an engine so mis-treated would be safe in operation.



Preparing to drive a 2-ton 1963 Buick sedan over 5 MPC Type B3-3 model rocket engines to see if they will be damaged.

Procedure: Five MPC Type B3-3 model rocket engines were placed on an asphalt surface that was also covered with loose gravel, offering many sharp points which could damage an engine. The right front wheel of a 1963 Buick sedan weighing about 4000 pounds was rolled over the five engines.

Results: No explosion or ignition of the engines took place. Immediately following the test, the engines were subjected to a static test, and all operated satisfactorily.



Driving over model rocket engines.



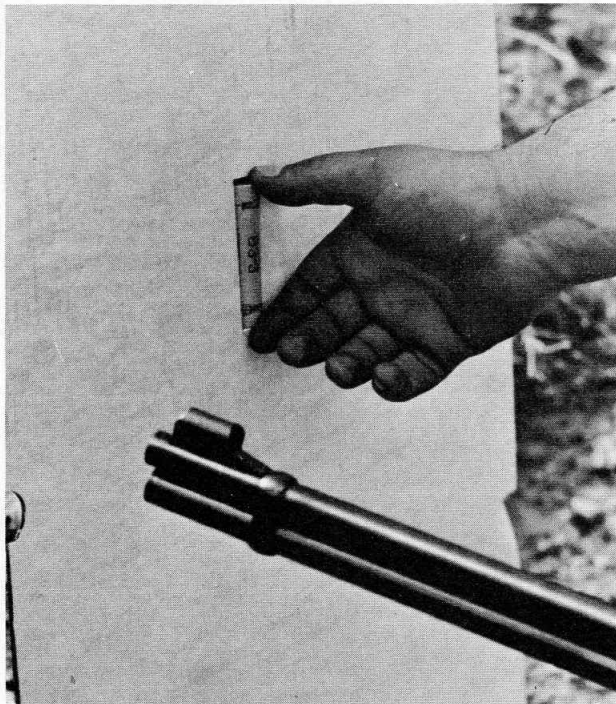
The result of driving over model rocket engines. There was no ignition or explosion. All engines were useable. Note that the surface of the road is rough, giving every opportunity for the engines to be punctured or damaged.

C. Bullet Impact Test:

Purpose: To determine if a model rocket engine would ignite or explode as a result of the physical shock, heat, and disruption caused by the impact of a rifle bullet.

Procedure: An MPC Type B3-3 model rocket engine was mounted on a piece of cardboard as a target. A 70-grain bullet from a Winchester 30-30 lever-action rifle was fired into the engine from a distance of 25 feet.

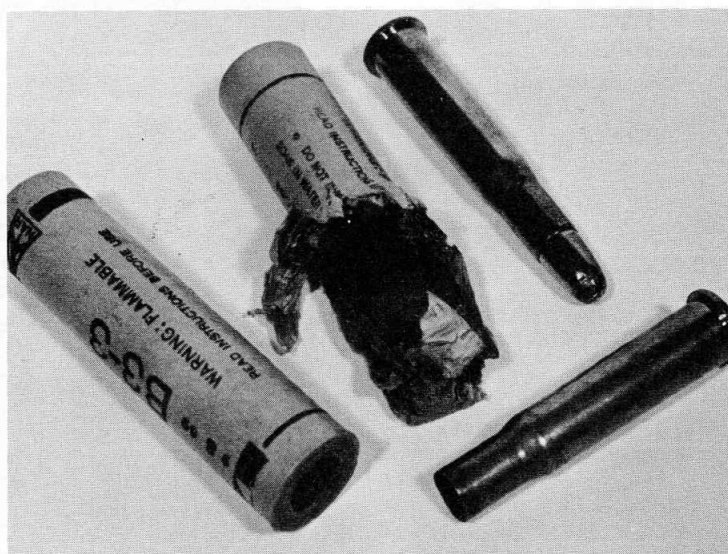
Results: No ignition or explosion of the model rocket engine propellant occurred. The bullet struck the engine at the interface between the propellant grain and the time delay charge. The paper casing ruptured from the impact. Approximately 75% of the propellant grain remained intact in the undisturbed portion of the casing.



Preparing to fire a Winchester 30-30 bullet into an MPC Type B3-3 model rocket engine to see if the impact would produce ignition or explosion of the engine.



Drawing a bead at point-blank range (25 feet) just before shooting a 30-30 bullet into an MPC Type B3-3 model rocket engine affixed to the cardboard target.

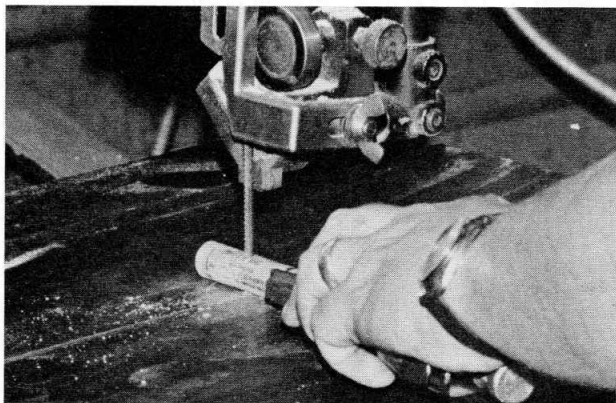


The results of the bullet impact test. Propellant did not ignite or explode even though the bullet destroyed the engine. An unharmed B3-3 is shown for comparison. Also shown are the 30-30 ammunition used in the test.

D. Band Saw Cutting Test:

Purpose: To determine whether or not a model rocket engine would explode or ignite if sawed in half.

Procedure: To produce a vigorous and constant sawing action, a Do-All band saw was used. The engine was cut directly in half through its diameter.



Sawing an MPC Type B3-3 model rocket engine in half with a high-speed band saw to determine whether this sort of maltreatment would cause it to ignite or explode. It did not.

Results: The engine was sawed in half in approximately 45 seconds with no explosion or ignition caused by heat generated by the sawing action.



The engine in front was sawed in half through the propellant grain using a high-speed band saw. It is evident that there was no ignition or explosion of the propellant.

E. Paper Fire Test:

Purpose: To determine if a model rocket engine would explode or burn when placed in a fire fuelled by newspaper, and the length of time required for ignition.

Procedure: Two sheets of full-sized newspaper were crumpled into a loose wad. Two MPC Type B3-3 model rocket engines were placed atop the burnable material. The newsprint was lit with a match.

Results: The fire died after three minutes. The two model rocket engines did not explode or ignite. The casings of both engines were slightly browned and scorched, but both engines were useable.



A fire built with newsprint with two MPC Type B3-3 model rocket engines involved.



The paper blazes away. Note model rocket engine in flames in front.



On left, model rocket engine from paper fire showing blackening of casing but no damage. Regular MPC B3-3 shown for comparison.

F. Gasoline Fire Test:

Purpose: To determine whether or not a model rocket engine would ignite or explode if placed in a puddle of burning gasoline.

Procedure: Two MPC Type B3-3 model rocket engines were placed on sandy ground which was saturated with approximately one pint of gasoline. The gasoline was ignited with a match.



Pouring a puddle of gasoline for the Gasoline Fire test.



Gasoline fire blazes away. Note MPC model rocket engine lying in flames in foreground of fire.



The gasoline fire went out after five minutes, leaving these MPC Type B3-3 model rocket engines. They did not explode. They did not ignite. Charring of the paper engine casing is evident.

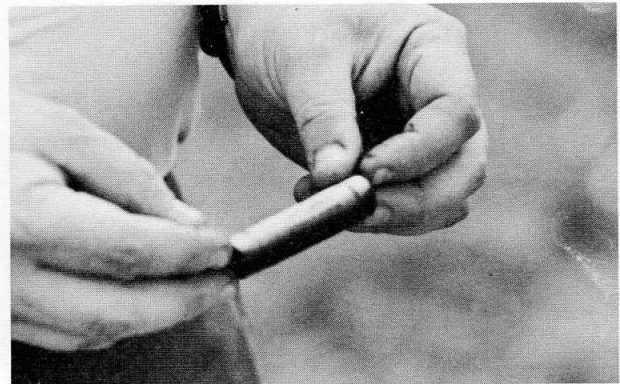
Results: The gasoline burned for approximately 5 minutes. The two model rocket engines did not ignite or explode. After the fire went out, the two model rocket engines were examined for damage. The upper half of each engine casing was covered with a layer of soot that was easily scraped off with a knife blade. The two engines were both useable.



Placing two MPC Type B3-3 model rocket engines in the gasoline-soaked sand of the test area.



Gasoline continues to burn. Note black-charred model rocket engine in fire.



Only the upper half of the engine casing was charred in the gasoline fire.

G.Sustained Fire Test:

Purpose: To determine if a model rocket engine would explode or ignite when placed in a sustained fire fuelled by wood, and the length of time required for ignition.

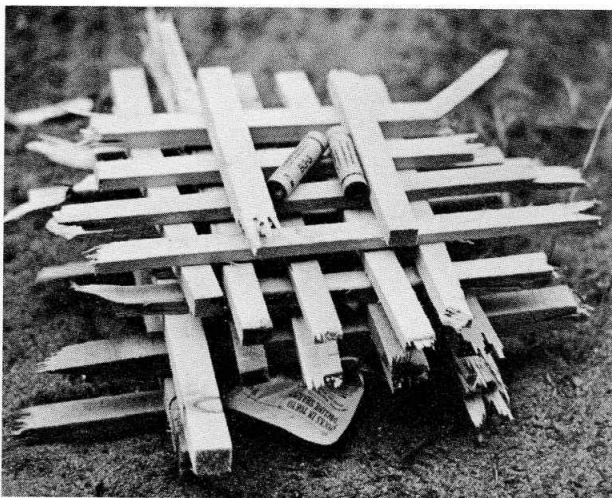
Procedure: A rick-type fire was built using pieces of green pine about ½-inch to 1-inch square and about 9-12 inches long. A crumpled sheet of newsprint was placed at the bottom of the rick as tinder and starter. Two MPC Type B3-3 model rocket engines were placed atop the rick where they would receive the greatest flame and heat, thereby having the greatest chance to ignite and/or explode at the earliest possible time.

Results: The rick fire blazed strongly, creating a bed of red-hot coals. After 5 minutes, one engine ignited and burned, propelling itself 6 feet from the fire and extinguishing itself. A few seconds later, the second engine ignited, propelling itself 3 feet from the fire and extinguishing itself. Subsequent close examination of the engines revealed that the fire had burned its way through the paper casing roughly halfway along the length, thereby exposing the propellant grain to the heat and flame of the fire which caused ignition. The propellant burned through the side of the casing in both instances, requiring less than one second to consume itself. The ceramic nozzles showed no evidence of dislodgement, propellant burning, heat, or flame which could have progressed up them to the propellant.

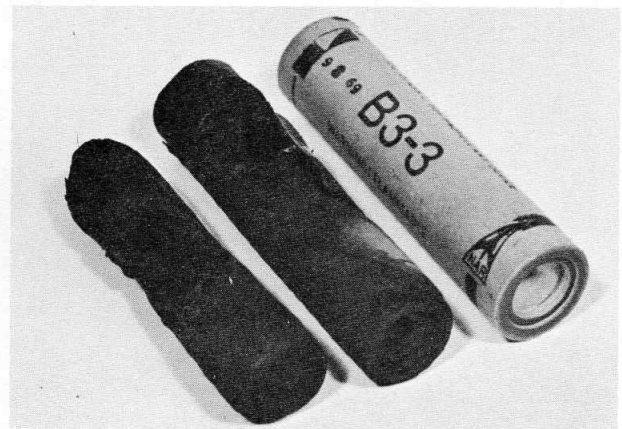
Under this identical condition a typical aerosol paint can would have exploded long before the Model Rocket Engine ignited. Model airplane glue and fuel would be burning prior to this as well.



The rick fire at T + 4 minutes.



The rick fire constructed to test sustained fire resistance of two B3-3 engines atop rick in hottest part of fire.



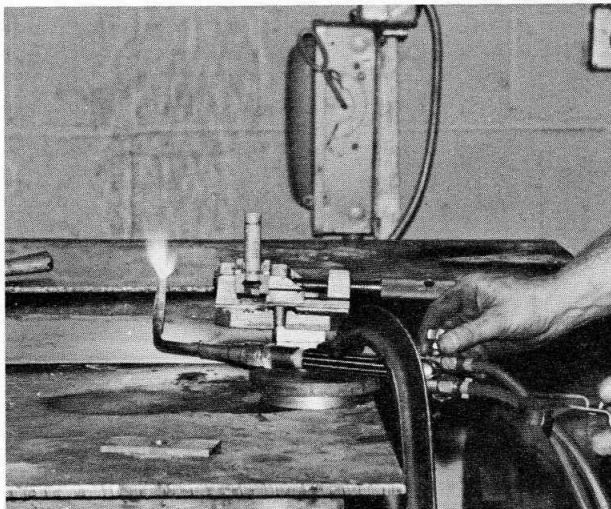
The two engines from the rick fire on the left compared against a regular Type B3-3. Both engines ignited after about 5 minutes because the fire burned its way through the paper casing as shown. Both nozzles indicated no propellant burning through nozzles.

H. Acetylene Torch Test:

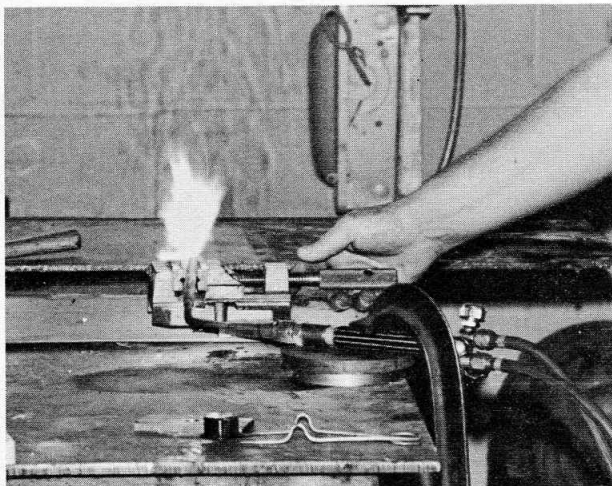
Purpose: To determine whether or not a model rocket engine would explode or ignite when the blue flame of an oxy-acetylene cutting torch was applied to the side of the casing, and to determine the amount of time required for explosion or ignition.

Procedure: An MPC Type B3-3 model rocket engine was clamped in a drill vise in a vertical position, nozzle-up. An oxy-acetylene torch was brought to bear on the side of the casing approximately halfway between the casing ends.

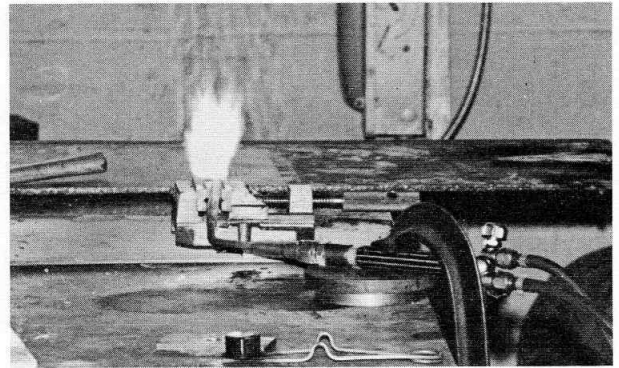
Results: The flame from the torch caused the paper casing to ignite and burn. 31 seconds after application of the flame to the casing, the casing burned through, exposing the rocket propellant to the flame. The propellant ignited and burned radially outward from the hole in the casing that had been burned through by the torch. There was no explosion.



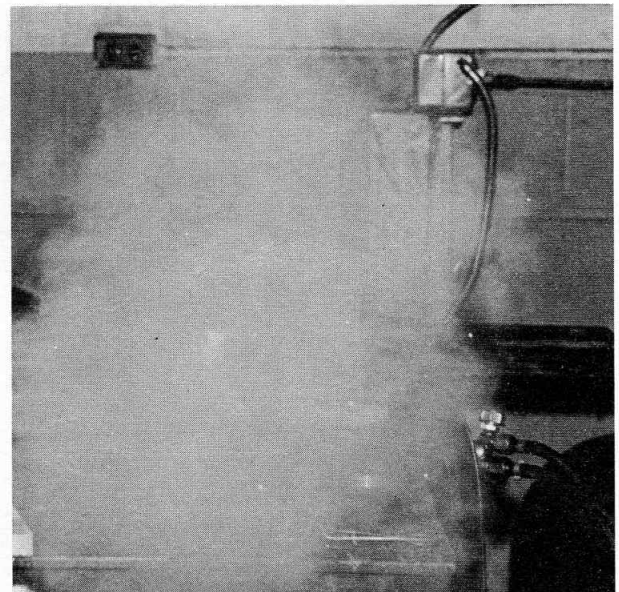
Set-up for the acetylene torch test using a welding torch directed against the side of an MPC Type B3-3 model rocket engine.



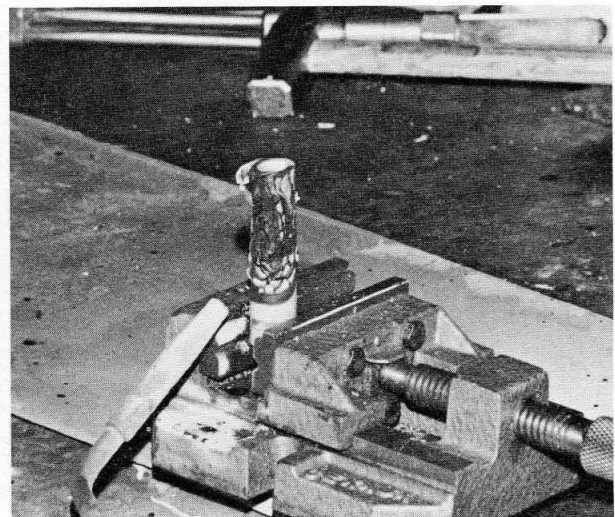
Acetylene torch test. T + 0.



Acetylene torch test. T + 20 seconds.



Acetylene torch test. T + 31 seconds. Ignition of propellant through side of casing.



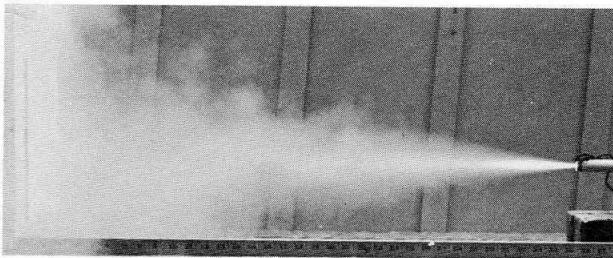
Acetylene torch test results. Note that torch burned through side of casing taking 31 seconds to do it. Propellant then burned through hole in casing side, NOT through nozzle. Note white nozzle on upper end of destroyed engine.

I. Exhaust Impingement Tests:

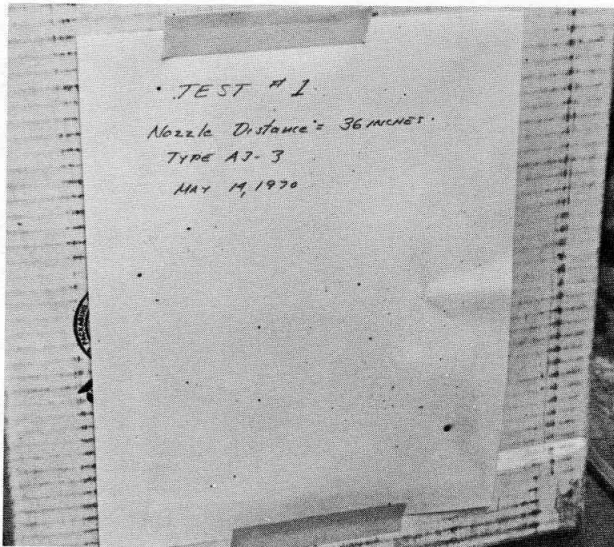
Purpose: To determine the fire hazard, if any, due to the exhaust jet of an operating model rocket engine at various distances from the nozzle.

Procedure: A sheet of 8-½" x 11" 20-pound white mimeo bond paper was taped to a frame in a vertical orientation. An MPC Type A3-2 model rocket engine was affixed in a drill vise with the axis of the exhaust jet directed perpendicular to the sheet of paper. The distance from the nozzle to the surface of the paper was measured for each test. The first test took place at a distance of 36 inches. Subsequent tests were conducted at 30 inches, 24 inches, 18 inches, 12 inches, 6 inches, 9 inches, and 12 inches respectively.

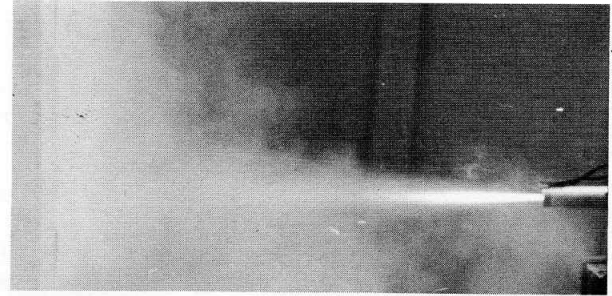
Results: The exhaust jet directly perpendicularly against a sheet of paper burned a series of random pin holes in the paper at a distance of 12 inches, and these pin holes were self-extinguishing. At a distance of 9 inches, a ragged hole was burned through the paper by the jet, but the charred edges were self-extinguishing. At a distance of 6 inches, a round hole 1.25 inches in diameter was burned through the paper and was self-extinguishing.



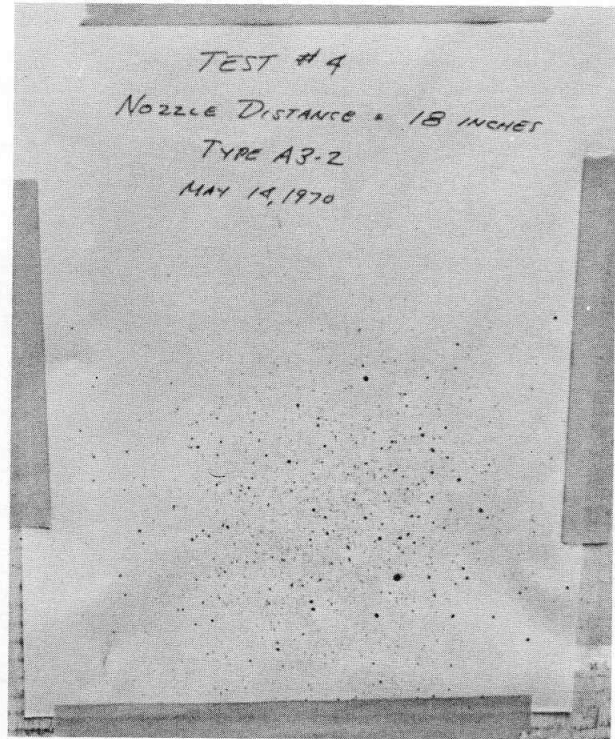
Exhaust Impingement Tests. To determine if there was any fire hazard from the exhaust jet, we directed it against a sheet of paper at varying distances. Here is the test at a distance of 36 inches.



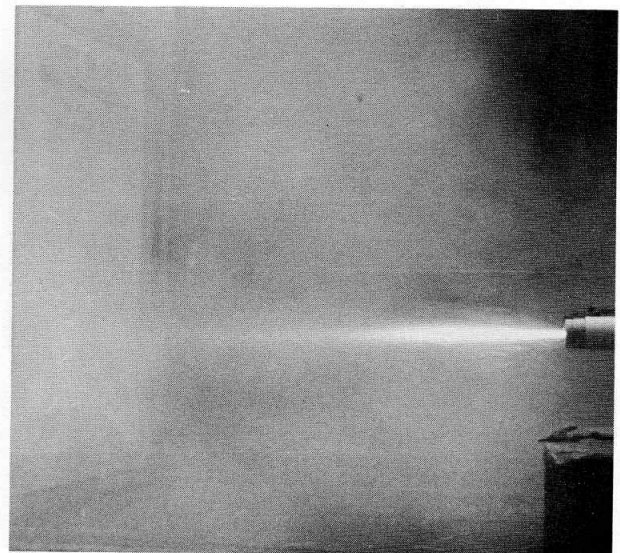
The test paper showing the results of firing an MPC Type A3-2 against it from a distance of 36 inches.



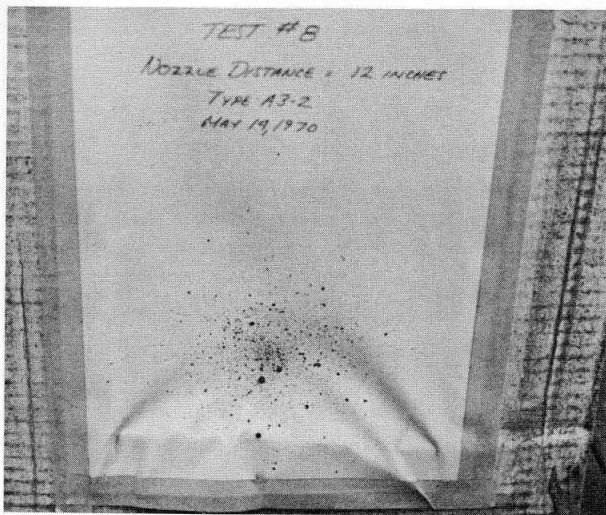
Exhaust impingement test at a distance of 18 inches.



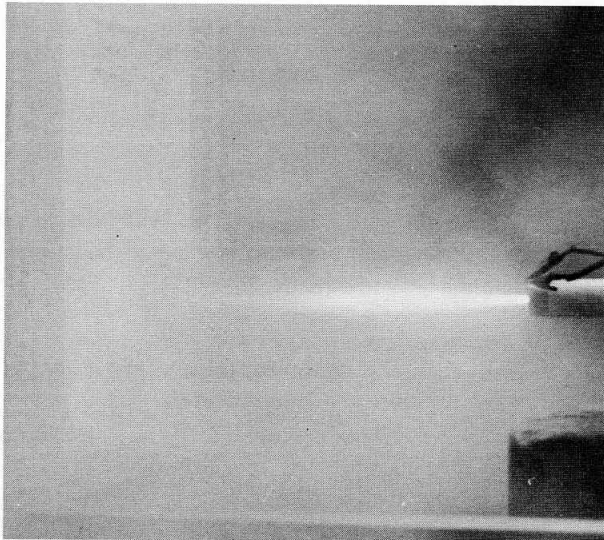
The results of the 18-inch test.



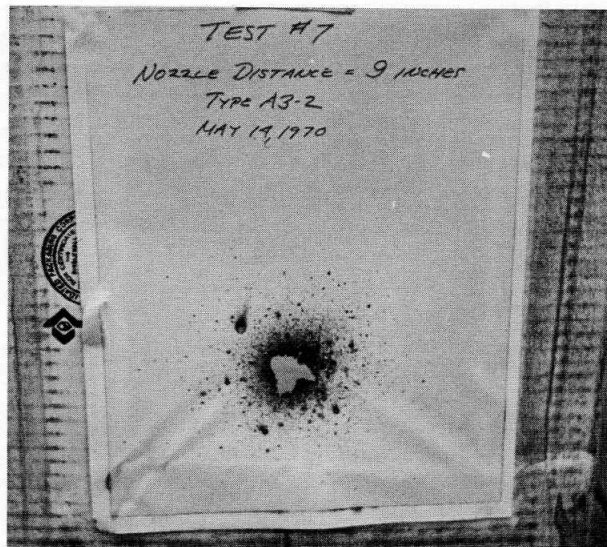
Exhaust impingement test at a distance of 12 inches.



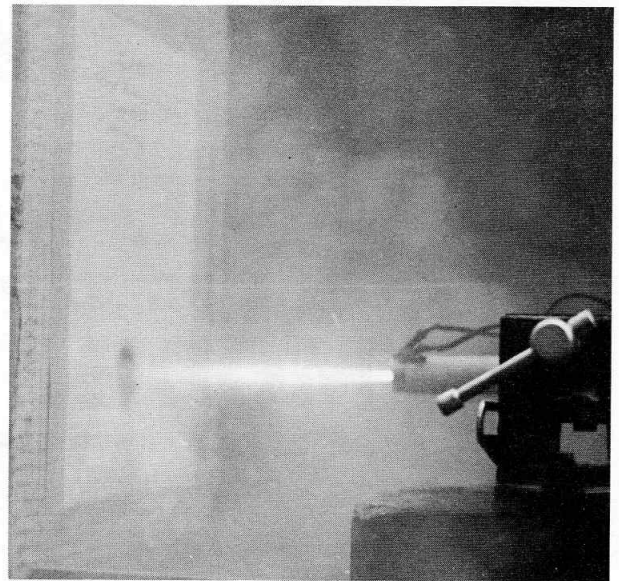
Results of 12-inch exhaust test. No burning of paper. Note that paper was billowed inward by the force of the jet.



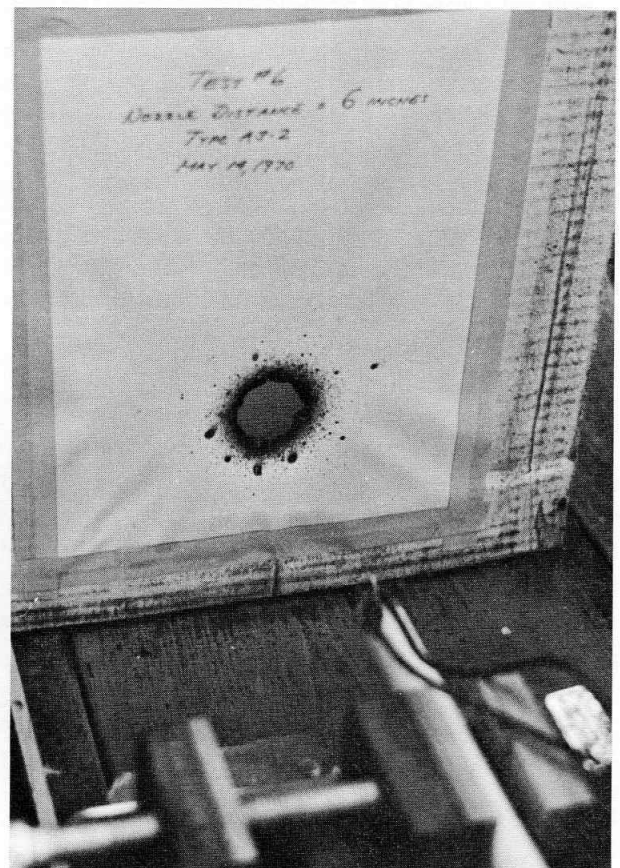
Exhaust impingement test at a distance of 9 inches. Note that the tip of the luminous jet just touches the paper.



Results of the 9-inch exhaust impingement test. A ragged hole has been burned in the paper. This was self-extinguishing.



Exhaust impingement test at a distance of 6 inches showing jet punching its way through the paper. Note that there is no fire or flame of the paper produced by the jet. This is because the velocity of the jet carries all heat directly through the paper and away.



Results of the 6-inch exhaust impingement test showing the ragged hole punched through the paper by the jet. This was self-extinguishing. The edges of the hole were bent away from the engine indicating the hole was literally punched through the paper by the speed of the jet.

Appendix 3



THE NAR-HIAA SOLID PROPELLANT MODEL ROCKET SAFETY CODE



1. CONSTRUCTION—My model rockets will be made of lightweight materials such as paper, wood, plastic and rubber without any metal as structural parts.
2. ENGINES—I will use only pre-loaded factory made model rocket engines in the manner recommended by the manufacturer. I will not change in any way nor attempt to reload these engines.
3. RECOVERY—I will always use a recovery system in my model rockets that will return them safely to the ground so that they may be flown again.
4. WEIGHT LIMITS—My model rocket will weigh no more than 453 grams (16 oz.) at liftoff, and the engines will contain no more than 113 grams (4 oz.) of propellant.
5. STABILITY—I will check the stability of my model rockets before their first flight, except when launching models of already proven stability.
6. LAUNCHING SYSTEM—The system I use to launch my model rockets must be remotely controlled and electrically operated, and will contain a switch that will turn to "off" when released. I will remain at least 10 feet from any rocket that is being launched.
7. LAUNCH SAFETY—I will not let anyone approach a model rocket on a launcher until I have made sure that either the safety interlock key has been removed or the battery has been disconnected from my launcher.
8. FLYING CONDITIONS—I will not launch my model rocket in high winds, near buildings, power lines, tall trees, low flying aircraft or under any conditions which might be dangerous to people or property.
9. LAUNCH AREA—My model rockets will always be launched from a cleared area, free of any easy to burn materials, and I will only use non-flammable recovery wadding in my rockets.
10. JET DEFLECTOR—My launcher will have a jet deflector device to prevent the engine exhaust from hitting the ground directly.
11. LAUNCH ROD—To prevent accidental eye injury I will always place the launcher so the end of the rod is above eye level or cap the end of the rod with my hand when approaching it. I will never place my head or body over the launching rod. When my launcher is not in use I will always store it so that the launch rod is not in an upright position.
12. POWER LINES—I will never attempt to recover my rocket from a power line or other dangerous places.
13. LAUNCH TARGETS AND ANGLE—I will not launch rockets so their flight path will carry them against targets on the ground, and will never use an explosive warhead nor a payload that is intended to be flammable. My launching device will always be pointed within 30 degrees of vertical.
14. PRE-LAUNCH TEST—When conducting research activities with unproven designs or methods, I will, when possible, determine their reliability through pre-launch tests. I will conduct launchings of unproven designs in complete isolation from persons not participating in the actual launching.

Appendix 4: NATIONAL ASSOCIATION OF ROCKETRY

Model Rocket Engine Standards

1. A model rocket engine shall be a solid propellant reaction engine produced by a commercial manufacturer. It shall have all of the propelling ingredients preloaded into the casing in such a manner that they cannot be easily removed. Delay trains and ejection charges may be included as an integral part of the engine or may be preloaded and packaged separately if (a) the auxiliary package is a single preassembled unit containing all of the remaining combustible material, and (b) the auxiliary package is so designed that the average person would have no difficulty handling or using it safely.

2. A model rocket engine casing shall be made of nonmetallic material of low thermal conductivity so that the temperature of the external surface of the model rocket engine shall not exceed 150 degrees Centigrade (302 degrees Fahrenheit) during or after operation.

3. A model rocket engine must be so constructed that, should it rupture its casing, the casing shall not fragment.

4. A model rocket engine must be so designed and constructed as to be incapable of spontaneous ignition in air, in water, as a result of physical shocks, jarring, impacts or motion under conditions that would reasonably be expected to occur during shipment, storage and use, or when subjected to a temperature of 80 degrees Centigrade (176 degrees Fahrenheit) or less.

5. A model rocket engine shall contain no more than 62.5 grams (2.2 ounces) of propellant material, and shall produce less than 80 Newton-seconds (17.92 pound-seconds) of total impulse with thrust duration not less than 0.050 seconds.

6. A model rocket manufacturer shall subject a random sample of one percent (1%) of each engine production lot to a static test which shall measure and record thrust, duration, thrust-time profile, delay time and strength of the ejection charge (if any). Model rocket engine lots must be corrected or destroyed by the manufacturer if:

a. The total impulse of any test item departs more than 20 percent (20%) from the established mean value for the engine type;

b. The time delay of the test item departs more than 20 percent (20%) from the established mean value for the engine type but in no event shall this variation exceed 3 seconds;

c. The ejection charge of the test item does not function properly;

d. The test item malfunctions in any other manner. Static tests shall be conducted with the test item at ambient temperature.

7. A model rocket engine type whose performance deviates from the sample test criteria detailed above within one year from the date of manufacture shall be withdrawn from commercial sale and redesigned to provide reliable operation when ignited within a period of one year from the date of manufacture. All model rocket engines shall have imprinted upon the exterior of their casings the date of manufacture.

8. A model rocket engine shall be shipped and stored with no igniter element installed that may be actuated by open flame at a temperature of less than 150 degrees Centigrade (302 degrees Fahrenheit), or by incident radio frequency radiation normally encountered in shipping, storage and use. No manufacturer, distributor, or any other person shall sell or otherwise make available to the public any type of model rocket ignition device that is intended to be initiated by a hand-held flame.

9. A model rocket engine shall be shipped and sold with complete instructions for storage, handling and use. These instructions shall contain a warning to read and follow all instructions carefully and to use the engine only in accordance with instructions. In addition, the instructions shall contain the following information:

a. How to safely ignite the engine by electrical means;

b. Performance data on the model rocket engine type to include propellant weight, total impulse, average thrust, time delay, and thrust-time curve;

c. Any special First Aid data or steps to be taken in the event of burns or if the propellant is orally ingested;

d. Proper and safe disposal of the engine if it has become too old, been subjected to conditions that may impair its performance, or in the opinion of the user may have become unsafe;

e. Special action to be taken in fighting any fire in which stored rocket engines may be involved.

10. A model rocket engine containing more than 25 grams (0.88 ounces) of propellant material shall be sealed at the factory with a non-flammable, nonmetallic seal in the nozzle and in the forward end, such seals to be readily removable by the user unless the engine is designed to perform its function with the seals in place.

11. A model rocket engine in operation shall not expell from its nozzle any pieces of burning propellant, and shall be incapable of igniting a piece of dry paper or grass at a distance from its nozzle 500 times the diameter of the nozzle throat.

Appendix 5:

BUREAU OF EXPLOSIVES

ASSOCIATION OF AMERICAN RAILROADS

REPORT FROM CHEMICAL LABORATORY

T. C. GEORGE, DIRECTOR AND CHIEF INSPECTOR

WILLIAM G. MCKENNA, CHIEF CHEMIST

FILE NUMBER 7 Toy Propellants
59689

LABORATORY NUMBER

EDISON, N. J., September 25, 1967

COPY

Class C Explosives

Toy Propellant Devices

MODEL ROCKET INDUSTRIES

Samples of a device identified as "Model Rocket Engines" were received from Model Rocket Industries of Madison, Wisconsin.

Each unit consisted of a pasteboard cylinder 2 3/4" long by 1 1/16" diameter closed at one end with a pasteboard disc and at the other with a clay plug with a hole in it.

Each device contained 5 grams of a mixture of binder, charcoal, sulfur and potassium nitrate.

The devices were stable when maintained at 75°C for 48 hours.

One of the units was clamped to a stand and an attempt made to ignite it with a safety fuse placed in the hole in the clay plug. The unit did not ignite. A fusee was placed under the end of the rocket and allowed to burn until the rocket ignited. It burned without explosion.

Devices represented by these samples are properly described as Toy Propellant Devices and classed as Class C Explosives under the DOT Regulations.

(NOTE: Tests were originally conducted on model rocket engines of identical design and construction produced by Model Rocket Industries; this company was acquired by Model Products Corporation in 1969. The report and the results, however, still stand, according to the Bureau of Explosives.)

C. W. Schultz
Assistant Chief Chemist

Appendix 6:



National Association of Rocketry

P. O. Box 178 McLean, Virginia 22101

AFFILIATED WITH THE NATIONAL AERONAUTIC ASSOCIATION

25 November 1969

Mr. Lee Jones
Model Products Corporation
1806 South Park Street
Madison, Wisconsin, 53713

Dear Mr. Jones:

COPY

Certification tests have been conducted on the MPC C-6-0 model rocket engine by the Standards and Testing Committee of the National Association of Rocketry. These tests indicate the sample engines sent to the Committee have the following characteristics:

Average Thrust	5.65 newtons
Average Duration	1.37 secs
Average Total Impulse	7.74 newton seconds
Variation of Total Impulse	$\pm 1.5\%$

Based on these data and supporting data provided by the manufacturer, all MPC C-6-0 engines manufactured November 1969 and subsequently, are granted both the NAR Safety Certificate and the NAR Contest Certificate.

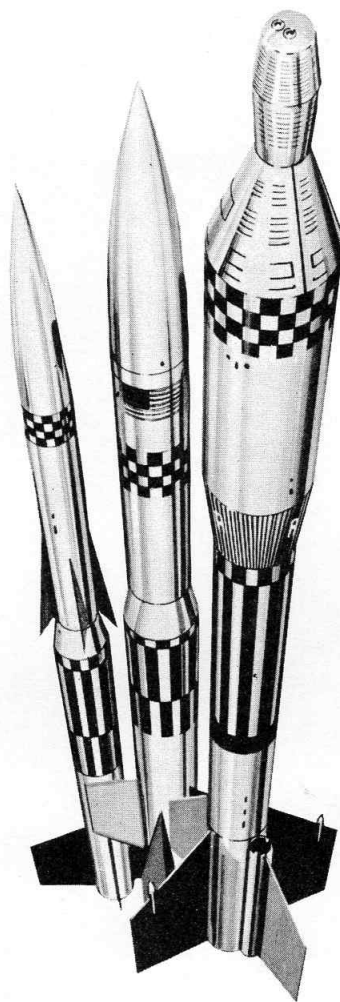
The Standards and Testing Committee would appreciate a small random sample of these engines - six engines every three months would be suitable - to assure product uniformity.
Thank you.

Sincerely,

G. M. Gregorek, Chairman
Standards & Testing Committee
National Association of Rocketry

(NOTE: All MPC Model Rocket engines presently produced and sold have been granted the Safety Certificate and the Contest Certificate of the National Association of Rocketry.)

NOTES:



First up with the new ideas



**MODEL
PRODUCTS
CORPORATION**
Mount Clemens, Mich. 48043

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