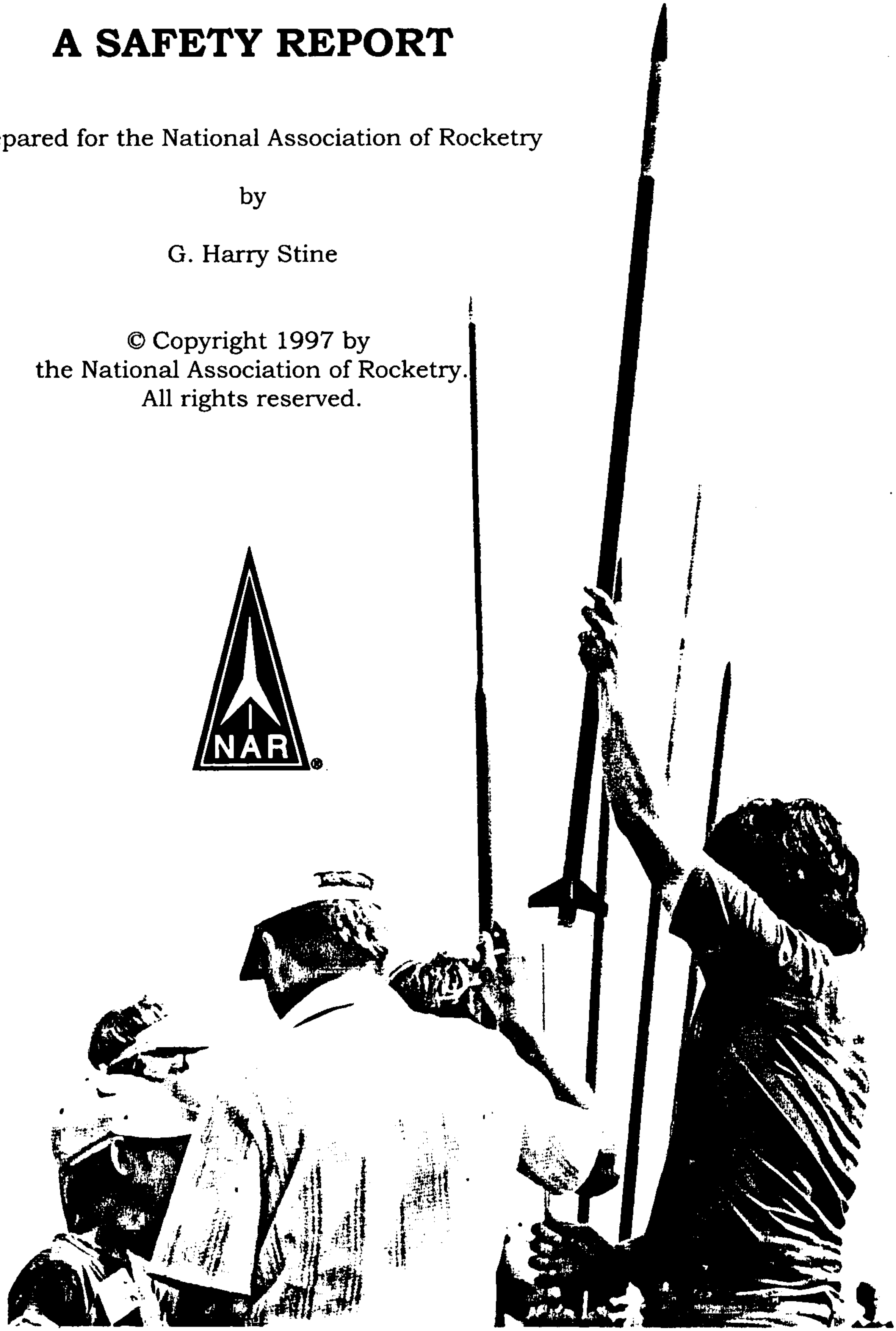
FORTY YEARS OF MODEL ROCKETRY

A SAFETY REPORT

Prepared for the National Association of Rocketry

by

G. Harry Stine



FOREWORD

This report was prepared specifically for those persons interested in the safety of model rocketry and model rocket motors. It describes the technology of the hobby. It summarizes the safety history of the hobby over a 40-year period. It summarizes the current rules and regulations governing the hobby including the endorsements of national, governmental, and civic organizations who have recognized the safe, educational, and recreational aspects of the hobby.

The hobby of model rocketry began in 1957 in response to the launching of the Soviet Sputnik satellites and the beginning of the Space Age. Many young people were hurt trying to build rockets and rocket motors without adequate knowledge, equipment, or safety precautions. Model rocketry was developed as a synthesis of model aviation, pyrotechnics, and professional rocket engineering. From model aviation came materials such as balsawood, paper, and plastic as well as construction techniques, bonding agents, and paints. From the ancient art of pyrotechnics came the inexpensive factory-made solid-propellant rocket motor. From professional rocket engineering came the quality control standards and procedures that elevated the model rocket motor to a professional level of safety and reliability, the aerodynamic principles that ensure safe and predictable flights with full recovery of the entire model, the safety precautions and operating codes that have made model rocketry the safest of all hobbies (except perhaps stamp collecting), and, finally, advanced model rocket motor technology that has continued to allow the manufacture of progressively safer and more reliable motors.

Basically, the safety success of model rocketry has resulted from:

(1) a factory-made, mass-produced solid propellant rocket motor of tested and proven design and predictable performance;

(2) positive control of the launch conditions using electrical ignition;

(3) airframes made from non-metallic materials such as paper, wood, and plastic that are light and strong but will absorb any impact energy by self-destructing;

(4) a recovery system that returns the model rocket safely to the ground in a condition to be flown again by repacking the recovery system and installing a new, factory-made model rocket motor.

An on-going program of quality control testing and retesting is carried out by the National Association of Rocketry (NAR) and the model rocket manufacturers to assure that products — especially model rocket motors — are produced that meet the strict national standards for safety, performance, and reliability of the National Fire Protection Association's NFPA 1122 "Code for Model Rocketry," the National Association of Rocketry's own NFPA-compatible standards, and federal regulatory requirements. In addition, model rocket components and systems have been tested and re-tested for 40 years to determine potential hazards and to reaffirm previous test results. Since 1957, people involved in the hobby and public safety officials have been constantly amazed and pleased by test results that have continued to indicate a higher level of safety than suspected. NAR and the model rocket manufacturers have continually worked to devise and conduct more difficult safety tests that would reflect the environments encountered in manufacture, shipment, storage, and use, probing the "edge of the envelope" of model rocket safety. The tests results often seem incredible, but they are repeatable.

The NAR and the model rocket manufacturers do not recommend that model rocket products by handled or misused in the manner required to perform the tests summarized in this report. If done at all by others than the NAR and model rocket manufacturers, such testing should always be carried out only by public safety officials who may be interested in checking these results. These tests are NOT intended for public demonstration or academic instruction.

Forty years after the hobby began, model rocketeers can proudly boast of about 500 million safe flights. There have been a few burned fingers but only one accident that could be classed as "serious" — a young spectator lost an eye as a result of improper construction and flight operations of a model rocket conducted by a science teacher before a class. ALL of the accidents in model rocketry have been caused by product misuse or failure to read and follow explicit instructions and safety rules. Considering the enormous number of model rocket flights — more than 20 million per year at the present rate — this safety record is better than that of Little League Football or even bicycle riding.

This is in direct contrast to an estimate made in 1957 by a professional rocket society that predicted more than one major injury in each *seven attempts to launch* a non-professional rocket.

Model rocketry's outstanding safety record is a result of a unique long-term co-operative effort between manufacturers, public safety officials, and users to develop, implement, and abide by workable controls and regulations at the manufacturing and distribution levels and simple yet explicit common sense safety rules at the user level. In these litigious times, manufacturers do not wish to produce unsafe products. Public safety officials don't want to be burdened by over-regulating something that has proved to be safe. Users want success, not accidents and injuries. Model rocketry's safety record has thus depended upon informed self-interest at all levels...and it has worked!

This report will show how and why this unique system has evolved and will strive to answer the most commonly-asked questions and allay the most commonly-held fears.

After 40 years, safety is still the top priority in model rocketry. But safety is no longer something that should be of critical concern to public safety officials, school officials, and other public servants. Indeed, many of them built and flew model rockets when they were young — many still do — and the contents of this report will hopefully be useful to them in convincing those who weren't model rocketeers when they were young.

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PART ONE

WHAT IS MODEL ROCKETRY?

Model rocketry is:

(a) an educational tool;
(b) a "technical recreation" or hobby.
(c) an international aerospace sport;

Who says so?

The National Fire Protection Association (NFPA)
The National Aeronautics and Space Administration (NASA)
The United States Air Force (USAF)
The United States Navy (USN)
The United States Army (AUS)
The Federation Aeronautique Internationale (FAI)
The International Astronautics Federation (IAF)
The American Institute of Aeronautics and Astronautics (AIAA)
The National Aeronautics Association (NAA)
The National Science Teachers Association (NSTA)
The Civil Air Patrol (CAP)
The 4-H Clubs of Ammerica
The YMCA/YWCA/YMHA/YWHA
The Boy Scouts of America

What is a model rocket?

A model rocket is an aerospace model having the following characteristics:

1. It is made of paper, plastic, wood, and other non-metallic materials without any metal as a structural part.

2. It weighs less than 3.3 pounds (1500 grams) and uses less than 4.4 ounces (125 grams) of rocket propellant in accordance with the standards of the NAR and the NFPA.

3. It uses a factory-made solid propellant rocket reaction motor. This motor may either be expendable or reloadable. This eliminates any hazard of compounding and mixing rocket chemicals by the user.

4. Its model rocket motor is ignited electrically from a distance of at least 15 feet using a low-voltage electrical source and a launch controller with safety features established by the standards of the NAR and NFPA.

5. It contains a recovery system 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 National Fire Protection Association NFPA 1122 Code for Model Rocketry.
B. The Federation Aeronautique Internationale Sporting Code, Section 4b.
C. The American National Standards Institute.
D. Federal law: Section 307, 72 Statute 749, 49 U.S. Code 1348, "Airspace Control and Facilities."

Is a model rocket a toy?

No. A flying model rocket is a scientifically-designed educational aero model, not a toy. It is capable of attaining speeds of more than 200 miles per hour. It should be used only as instructed in accordance with all safety codes.

How long does it take to build a model rocket?

Some model rockets are available as carefully-designed almost-ready-to-fly models requiring little or no skill on the part of the user; they can be launched within minutes by preparing the recovery device and installing a model rocket motor. Simple model rocket kits can be assembled with ordinary hobby tools and glue in thirty minutes while others require more time. Complex scale models and advanced high-performance model rockets often take weeks or months to assemble.

What is required to fly a model rocket?

A flying model rocket is but one part of a system consisting of the model itself, a model rocket motor, a launch pad, an electrical launch control device, an electrical igniter for the model rocket motor, and a source of 6-volt or 12-volt electricity such as a battery.

How does a model rocket operate?

Ignition of the model rocket's motor is accomplished electrically by the user at a distance of 15 feet or more from the launch pad.

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

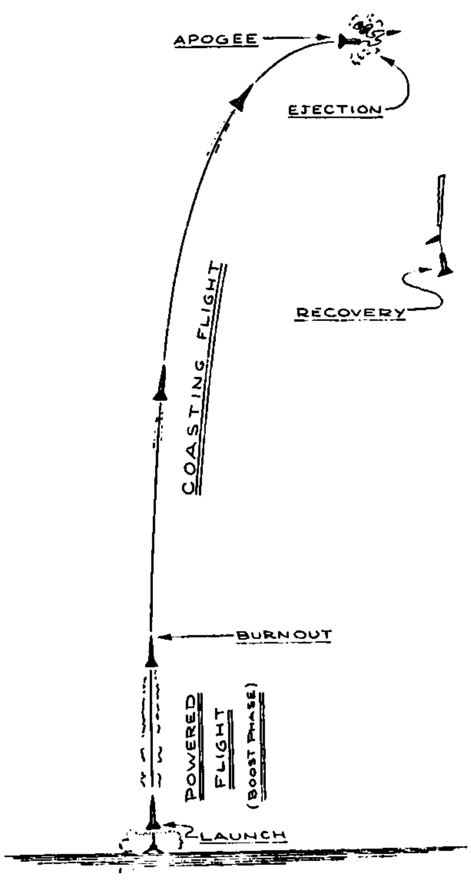
At the end of powered flight after a rocket motor thrust period varying from 0.2 seconds to as long as 10 seconds (depending upon the type of model rocket motor chosen by the user), the model rocket may be 50 to 500 feet in the air and moving straight up at a speed of 100 miles per hour or more. Some advanced model rockets have reached the speed of sound.

Following the thrust phase of the flight, a time-delay element in the model rocket motor is automatically activated, permitting the model rocket to coast upward for several seconds to its peak altitude (apogee).

At or near apogee and at a pre-determined time after ignition — pre-selected by the user in choosing the type of model rocket motor to be used for the flight — the recovery ejection charge in the model rocket motor activates. This produces a retro-fire puff of gas that pressurizes the inside of the hollow body tube, forcing the recovery device forward to dislodge the nose. (For further technical details on the operation of a model rocket motor, see Part Two of this report.) Some models use more complex mechanisms activated by the ejection charge. The recovery device —a parachute, streamer, helicopter rotor, or gliding wing — then deploys. Parachutes and streamers are the most commonly-used recovery devices. The entire model rocket with all its parts tied together then returns to the ground in a gentle manner so that it's undamaged and can be prepared for another flight.

Another flight can be made almost at once. The user re-packs the recovery device and installs a fresh model rocket motor and electrical igniter in the model rocket.

Some model rockets have flown more than 100 times.



What are the parts of a simple model rocket?

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

a. A hollow plastic or balsawood aerodynamically-shaped nose that can come off the model.

b. A light-weight, hollow plastic or paper body tube that is also the main structural airframe part.

c. One or more launch lugs affixed to the size of the body tube that in turn slip over the guide rod of the launch pad.

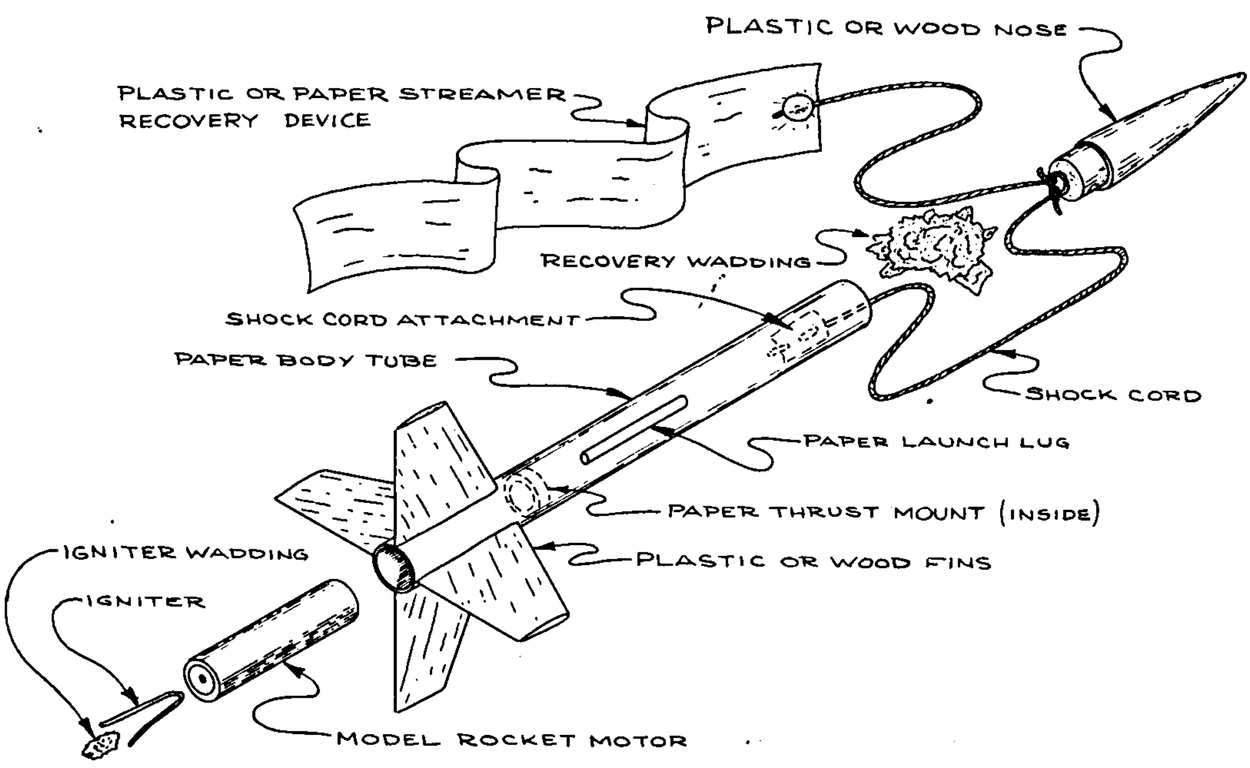
d. A recovery device such as a plastic or nylon parachute or a simple plastic streamer that is packed inside the body tube and ejected forward by a "retro-fire" action of the model rocket motor at a predetermined time in the flight at or near maximum altitude or apogee.

e. A replaceable factory-made, mass-produced solid propellant model rocket motor of tested performance quality along with the thrust mount and retainer that hold it properly in the model rocket airframe. Model rocket motors are usually one-use expendable units, but advanced model rocket motors may be reloaded using materials manufactured and intended for this purpose.

f. Fins made of plastic, balsawood, paper, or plywood which keep the model rocket travelling in a predictable flight path like fletching feathers on an arrow.

g. Expendable, non-flammable, bio-degradable wadding or an internal baffle system to protect the recovery device from the retro-fire action of the model rocket motor.

h. An electrical igniter to start the model rocket motor.



How is a model rocket recovered?

The means used to recover a model rocket depend upon the design, construction, and weight of the model. Plastic parachutes or streamers are the most commonly-used recovery devices. However, airframe tumbling, deployment of helicopter rotors, and gliding are also used in advanced model rockets. If the model is designed to separate into two or more parts for recovery, each part must be lowered by a recovery device. The basic concept is to allow all parts of the model rocket to return to the ground safely and gently so the model rocket can be flown again by re-packing the recovery system and installing a fresh model rocket motor.

Who are the model rocketeers?

Model rocketeers range in age from 8 to 80 and include men and women as well as boys and girls. Most young people involved in the hobby are about 13 years old. More than 50% of the model rocketeers are adults, some of whom started building and flying model rockets when they were teen-agers. For 40 years, model rocketry has shown itself to be an outstanding parent-child activity, and many old-time model rocketeers are now guiding their children into the hobby because model rocketry appeals to such a broad spectrum of age groups. A parent can use model rocketry to teach children many things beyond the simple activity of putting together a model rocket kit and flying it. Most of the people involved are interested in science and technology and are highly intelligent. A study conducted among students in Pennsylvania indicated that a model rocketeer has an average I.Q. of 141.

Is there a minimum age for a model rocketeer?

Experience indicates that children less than 10 years old may have the enthusiasm but not the necessary manual skills to build a model rocket without adult supervision and assistance although they are certainly capable of operating the simpler "ready-to-fly" model rockets. The instructions and safety rules that accompany every model rocket kit are simple, visual, and easy to understand. Decades of experience have showed that people, young and old, will follow good instructions and observe reasonable and understandable safety rules because they want success. All model rocket manufacturers, however, recommend adult assistance and supervision in building and flying model rockets for those children under 12 years of age. (This is no longer considered mandatory as it was 30 years ago by the NFPA and other organizations.) Adult supervision is recommended because a young rocketeer's enthusiasm and excitement could cause him to overlook some important point in the pre-flight sequence; the "double-check" feature of adult supervision can often prevent mistakes made in haste and excitement. However, it's fair to point out that model rocketry's safety record has NOT depended upon adult supervision and that all mistakes made in haste and excitement were non-hazardous in nature and result. The adult presence merely helps assure the important element of success.

Is model rocketry a learning tool?

Yes, it's a learning tool in disguise. Science and industrial arts teachers have discovered that model rocketry is a useful and motivating adjunct to academic studies. Since model rocketry combines modern science and technology, craftsmanship and shop practice, individual creativity, and group co-operation in the pursuit of a goal with a healthy outdoor activity, model rocketry isn't confined to young students; many universities have model rocket clubs. Sportsmanship, craftsmanship, self-reliance, discipline, and pragmatic approaches to problems are areas in which model rocketry excels. The hobby has been used with both high-achievement students and disadvantaged or handicapped youngsters because, if the simple rules and instructions are followed, a successful flight is a certainty — and for many of these young people, it may be the first successful thing they've ever done.

Among adults, printers, insurance salesmen, photographers, artists, business executives, rocket engineers, museum directors, recreation directors, and school teachers are included among the five million-plus model rocketeers in the United States.

What does it cost?

A complete model rocket "starter set" consisting of a model rocket, a launch pad, an electrical launch controller, model rocket motors, and electrical igniters is available in various levels of complexity and cost ranging from $25.00 up. Components may be purchased separately. The price of a model rocket motor ranges from $1.00 up. The larger the model rocket and the more powerful the model rocket motor, the higher the price. This economic factor acts to concentrate the majority of youth model rocket flying in the "low performance area of the flight envelope" while more affluent adults are the ones able to purchase the more complex and costly high-performance model rocket equipment. This cost factor also tends to mitigate the purchase of model rocket equipment for deliberate misuse; it costs too much as well as requiring some intelligence to use.

Is model rocketry dangerous?

On the basis of 40 years of public experience and about 500 million model rocket flights, it is possible to state categorically that model rocketry is not dangerous if done in accordance with established and tested safety rules *just like every other human activity*. The majority of accidents thus far have involved such injuries as minor burns. *All incidents have been caused by failure to read and follow the simple instructions and safety rules.* On the basis of an established record, model rocketry is safer than swimming, boating, bicycling, baseball, football, and nearly every other hobby and sport. There is no question that model rocket equipment can be misused just like every other hobby and sport item. After all, a baseball bat can be turned into a lethal club. Because of the early perceived potential for misuse of model rocket equipment leading to injuries, it is truly surprising that the record shows surprisingly little of this.

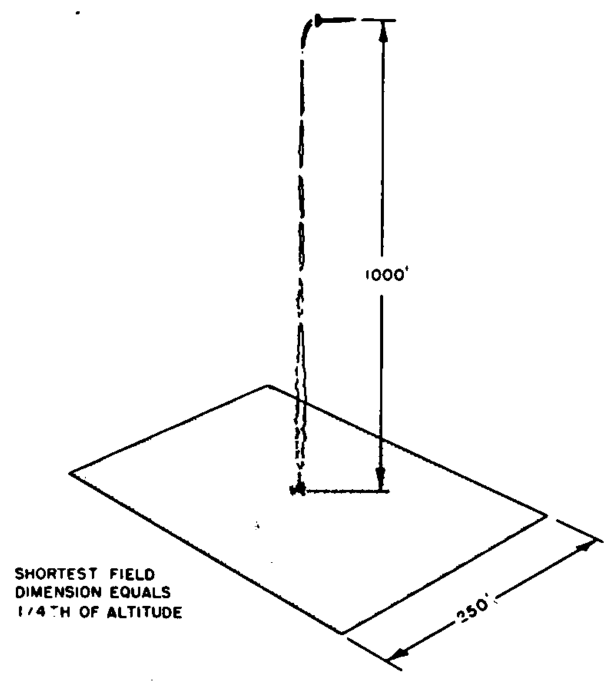
Model rocketry is the safest of all hobbies except perhaps stamp collecting.

How much room is needed to fly model rockets?

Model rocketeers like to fly in the largest available open area so they can get their models back. The biggest problem faced by a model rocketeer involves trees in which descending parachutes and streamers can become snagged.

To determine the shortest dimension of an open area to be used for flying model rockets on a relatively calm day, divide the expected altitude of the model rocket by 4. The flying field should have no horizontal dimension shorter that this number expressed in feet.

For most model rockets propelled by NAR Type A through Type C model rocket motors, a ground area the size of a football field is usually adequate. Model rocket flight demonstrations have been successfully and safely conducted thousands of times on airport ramps, outdoor civic plazas and parks, and even in such places as the Houston Astro-Dome during halftime of a Blue Bonnet Bowl before tens of thousands of people.



Are model rockets a hazard to aircraft?

No. The NAR has conducted comprehensive tests to confirm this. Aircraft face a far greater hazard from bird strikes, foreign objects on a runway, and hail. All jet engines are designed to ingest 4-pound birds and continue to operate. At a national competition, a Cessna-152 flew into a model rocket which disintegrated into a cloud of balsa and paper pieces.

The NAR Model Rocket Safety Code requires that model rockets not be flown into clouds or when aircraft are present over the flying site. This effectively eliminates any potential aircraft hazard. It should also be noted that neither the NAR or the Federal Aviation Administration have any restrictions against flying model rockets within 5 miles of an airport.

The chances of a model rocket actually hitting an aircraft in flight are so vanishingly small as to be insignificant. The U.S. Department of Defense has had to develop very expensive and highly complex multi-million-dollar guided missiles in order to deliberately hit airplanes.

However, it is not recommended that model rocketeers set up flying sites in the approach and landing zones of airport runways. The pilot of an airplane taking off or landing has plenty to do without worrying about model rockets. Several national championships and two international World Championships have been held in the middle of active airports where aircraft operations were not affected. As long ago as 1959, model rockets were part of airshows with no hazard to aircraft and no complaints from some of the world's finest civil and military pilots.

Model rockets may be operated without clearances or waivers from the Federal Aviation Administration (FAA).

What are model rocket manufacturers doing about safety?

In addition to following the national standards established by the National Fire Protection Association in NFPA 1122 "Code for Model Rocketry" and NFPA 1125 "Manufacture of Model and High Power Rocket Motors," the general policy of model rocket manufacturers is this: If it isn't safe, it won't be produced and sold. This is because (a) a tradition of 40 years must be maintained, (b) the hobby was originally created to solve the safety problem of young people trying to make their own rocket motors, not to create a new safety problem, and (c) in this litigious culture, any manufacturer who doesn't produce a reasonably safe product will not long remain in business.

Model rocketry was founded upon the principle of self-policing by manufacturers and users alike. All are well aware that if they don't police themselves, public safety officials and government regulators will step in to do it...and the results may not be palatable to either manufacturers or users.

In pursuit of these goals, all model rocket manufacturers do the following:

1. A copy of the NAR Model Rocket Safety Code is enclosed in each model rocket kit and with every sealed package of model rocket motors.

2. Complete instructions for assembly and use are included in every model rocket kit and package of model rocket motors.

3. All products meet or exceed the standards established by the NAR and set forth in NFPA 1122 Code for Model Rocketry.

4. All model rocket motor types are tested and certified as meeting NFPA standards by the NAR's Standards & Testing Committee.

5. All publications, catalogs, and other printed material from model rocket manufacturers stress safety and the scientific approach to model rocketry.

6. All model rocket manufacturers establish and maintain close co-operative liaison with safety officials at all levels of government, cooperate with the NAR, and participate in the activities of the NFPA's Technical Committee on Pyrotechnics.

What is the National Association of Rockertry?

The National Association of Rocketry (NAR) is a not-for-profit organization of unpaid volunteers who are model rocketeers, NAR is the primary U.S. consumer organization for model rocketry. NAR has thousands of members of all ages, most of them organized into local clubs. NAR membership is reasonable in cost and includes a subscription to *Sport Rocketry* magazine published every two months by the NAR and *The Model Rocketeer* newsletter published in alternate months. Liability insurance coverage for members, clubs, and third parties is available from the NAR at a reasonable cost.

Under the provisions of NFPA 1122 Code for Model Rocketry, the NAR tests all model rocket motor types produced for sale in the U.S. to ascertain they meet NFPA standards. Model rocket motor types bearing the triangular NAR logo have been certified by NAR as meeting or exceeding these standards. The NAR also conducts random sampling tests of production model rocket motors purchased from retail stores around the country. Model rocket motor types are re-tested and recertified on a regular schedule.

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The NAR maintains close liaison and co-operates with various government agencies such as the Consumer Product Safety Commission and public safety organizations such as the Fire Marshal's Association of North America. Since 1967, NAR has played an active role on the Technical Committee on Pyrotechnics of the National Fire Protection Association.

Further information about the NAR may be obtained by writing to NAR Headquarters, 1311 Edgewood Drive, Altoona WI 54720, calling 800-262-4872, or visiting the NAR's Internet web site at:

http//www.nar.org.

or the e-mail address:

narhq@eau.net

PART TWO

THE HOW AND WHY OF A MODEL ROCKET MOTOR

What is a model rocket motor?

A model rocket motor is a small reaction propulsion motor designed and manufactured to stringent national standards relating to quality control, safety, and performance limits. It is intended to propel a model rocket into the air and to activate the model rocket's recovery device at the proper time in flight. All current model rocket motors use solid propellants.

What is a solid rocket propellant?

A solid rocket propellant is a mixture in solid form of a fuel (something to burn) and an oxidizer (something for the fuel to chemically combine with and burn). Various types of solid propellants also contain other chemicals that control the burning rate, storage stability, and other safety factors.

What solid propellants are used in model rocket motors?

Two types of solid propellants are used in model rocket motors.

One type of model rocket motor uses a highly-refined form of black powder whose oxidizer is potassium nitrate (KNO_3) with a fuel and binder consisting of carbon and sulfur. The characteristics of this rocket propellant are well-known and highly predictable. It has the lowest energy content (thrust produced per unit weight of propellant consumed, called "specific impulse" by rocket engineers) of all commercially available propellants. It is dead-pressed into the model rocket motor casing by hydraulic pressure in a motor-making machine. Practically all black powder solid-propellant model rocket motors are made by automatic loading machinery. Black powder is primarily used in small model rocket motors ranging from Type ¼A to Type D. More than 95% of the model rocket motors sold and used since 1958 have been black powder model rocket motors.

A second type of model rocket motor uses a "composite" solid propellant of the sort originally developed in 1942 to provide takeoff rocket boost (JATO) for heavily-laden military aircraft. Since then, composite propellants have been technically refined and improved for military missiles and space launch vehicles. The composite propellant used in a model rocket motor uses ammonium perchlorate (NH_4ClO_4) as an oxidizer in a binder/fuel that is an organic elastomer such as synthetic rubber. Various chemicals are added to control stability, ignition temperature, and burning characteristics. Unlike black powder that must be physically dead-pressed into a motor casing to form a propellant charge or "grain," a composite propellant is usually cast and cured in the motor casing (although it may also be cast in molds and later inserted into the casing). Composites have two to three times the specific impulse (thrust produced per unit weight of propellant consumed) of black powder. Composites are normally used in larger model rocket motors ranging from Type D to Type G. The production process of composite solid propellant model rocket motors does not readily lend itself to mass production by automatic machines as in the case of black powder model rocket motors. Therefore, composite model rocket motors tend to be more expensive.

What's inside a model rocket motor?

Regardless of whether a model rocket motor uses black powder or a composite propellant, the design and operation are basically the same. Please refer to the drawing of a "generic" expendable model rocket motor which shows the location of the various parts and ingredients as though the motor were cut lengthwise down the middle to reveal the interior.

The casing is a tube with carefully controlled dimensions. It may be made from convolutely-wound paper or from thermosetting plastic material. Reloadable model rocket motors discussed later use 6061-T6 aluminum motor casings.

The rocket nozzle is formed of dead-pressed ceramic material or, for some composite propellant model rocket motors, machined or molded high-temperature phenolic plastic. It has the distinctive shape of a "de Laval" nozzle used on all rocket motors. The size and alignment of the narrowest portion or "throat" is carefully controlled during manufacture. The throat size determines such parameters as internal combustion pressure and exit gas velocity (and therefore thrust) while careful nozzle alignment ensures that the motor's thrust force goes through the centerline or center of gravity of the model.

The propellant is a solid piece (or several solid pieces in a reloadable model rocket motor) of material having known and controlled combustion or burning characteristics dictated by its shape, density, and composition. Further details may be found in Part Three of this report that deals with the internal ballistics of the model rocket motor.

The time delay is made up of propellant-like material with much slower burning characteristics. It does not produce measurable thrust. It acts as a time delay element between the thrust-producing propellant and the ejection charge.

The ejection charge consists of approximately 0.3 to 0.5 grams of either black powder or granulated composite propellant — less material that in a .22-long cartridge. It is initiated by the end-of-burning of the time delay.

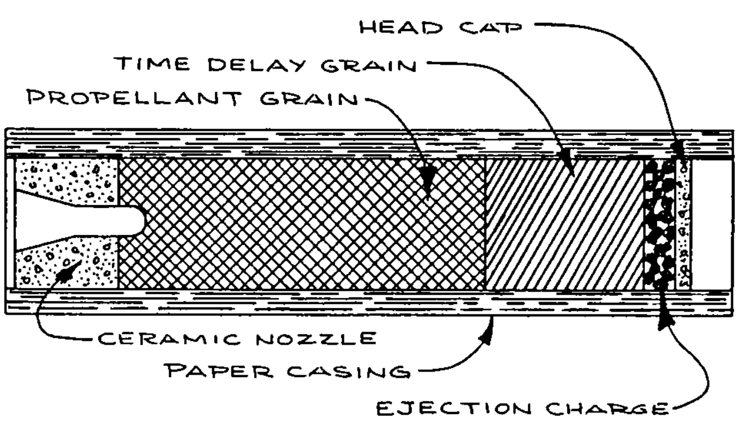
The ejection charge is held in place either with a paper cap or a thin layer of ceramic.

How does a model rocket motor work?

An electrical igniter must be used to start a model rocket motor. An igniter consists of two electrical lead wires terminating in a high-resistance electrical element coated with a few grains of chemical "squib" material. The igniter is inserted into the nozzle of the model rocket motor by the user in a manner specified by the manufacturer in the operating instructions. Igniters inserted in most black powder model rocket motors are simply pushed up the nozzle until they are in contact with the propellant, then held in place by tape or a special nozzle plug. A composite-propellant model rocket motor must have the igniter installed in a specific manner detailed in the instructions.

The electrical resistance of a model rocket igniter is usually about 0.4 ohms and requires 0.5 amperes at 6 volts DC to initiate the squib material.

The temperature of the propellant in both black powder and composite propellant model rocket motors must be raised to at least 550° F to initiate com-



bustion of the propellant. In order to ignite and burn, most composite solid propellants must also be under pressure from the gas liberated by the combustion of the squib material.

Once ignited, the propellant burns *only on its surface*. Most black powder model rocket motors use an "end-burning" propellant grain configuration that is ignited at the rear and burns progressively forward. Composite propellant model rocket motors usually have "core-burning" propellant grains with one or more specially-designed voids or holes running lengthwise through them with the propellant grain burning from the center or near-center outward toward the casing. The burning rate and therefore the volume and pressure of the gas generated is controlled by the shape of the propellant grain that is undergoing combustion at any given instant.

All combustion of the rocket propellant takes place inside the motor casing.

The design of model black powder model rocket motors is such that the propellant burns at a temperature of about 2,300° F and a pressure of around 100 pounds per square inch (psi), producing about 2,000 cubic inches of combustion gas for each ounce of propellant burned. Composite propellants operate with combustion temperatures around 4,200° F at pressures of about 500 psi also producing about 2,000 cubic inches of combustion gas for each ounce of propellant consumed.

The combustion gas rushes out of rocket nozzle in the rear end of the motor casing, its temperature and pressure dropping as it passes through the nozzle. As it leaves the nozzle, it is at or near atmospheric pressure. Black powder model rocket motors have an exhaust temperature of about 540° F and a velocity of about 2,650 feet per second (about 1,800 miles per hour). Composite propellant model rocket motors have an exhaust temperature of about 2,000° F and a velocity of about 7,000 feet per second (about 4,800 miles per hour).

The exhaust jet of a model rocket motor is NOT a flame. No combustion takes place outside the motor casing. Most model rocket motors produce a jet of luminous gas.

This rearward rushing gas produces a thrust force that propels the model rocket through the air. Because the amount of propellant under combustion at any given instant can be determined in advance by proper propellant formulation and grain design, the instantaneous thrust of a model rocket motor can also be controlled and tailored to the requirements of model rocket flight.

Once the propellant is exhausted, the time delay is automatically ignited. This produces no thrust and allows the model rocket to coast upward on its momentum. The time delay charge of most model rocket motors contains a chemical that produces a smoke trail so that model rockets may be seen and tracked in flight.

When the time delay is exhausted, it automatically ignites the ejection charge.

When the model rocket is recovered, the expendable model rocket motor casing is removed and discarded. An expendable model rocket motor casing, once used, should not be used again.

Can the propellant be easily removed from an expendable model rocket motor?

No. It is totally enclosed in a thick paper or plastic casing. With a sharp knife, a lot of time, and considerable patience, it's possible to remove the propellant. However, it is much easier to get the gun powder out of a shotgun shell. When the fire marshal of a large New England city once asked if the propellant could be removed, he was given a Type C motor and invited to do so. After five minutes of carving, he finally gave up.

Although it *is* possible to remove the propellant, the result is a solid cylinder of dirty black material. It will only burn with a bright flame.

Opening an expendable solid propellant model rocket motor is a difficult and time-consuming way to get combustible material. Far easier and cheaper methods are available.

Are all model rocket motors expendable, single-use units?

No. Some model rocket motors are now specifically designed to be reloadable. "Reloads" evolved as a result of improved composite propellants and motor casing materials.

Reloadable hobby rocket motors were introduced into model aviation in 1947 with the British "Jetex" units. These motors used a very slow-burning propellant that did not produce enough thrust to safely propel a model rocket in vertical flight; Jetex motors were used in winged model airplanes that climbed in slow spirals under the low thrust. They used aluminum casings that grew very hot during operation. Jetex rocket motors were standard off-the-shelf hobby products for about 30 years before importation by American Telasco ceased.

Modern reloadable model rocket motors were first made available in the late 1980s.

A cross-section drawing of a typical reloadable solid-propellant model rocket motor is shown in the accompanying figure.

By NAR and NFPA standards, the motor casing is fabricated from seamless 6061-T6 aluminum. Casing design minimizes fragmentation should the motor undergo a "catastrophic dis-assembly." The end closures are usually assembled using threads although some designs use snap-rings.

The rocket nozzle is usually machined from thermosetting plastic and must be replaced after each use.

The time delay grain and the ejection charge are pre-packaged units that fit into the casing.

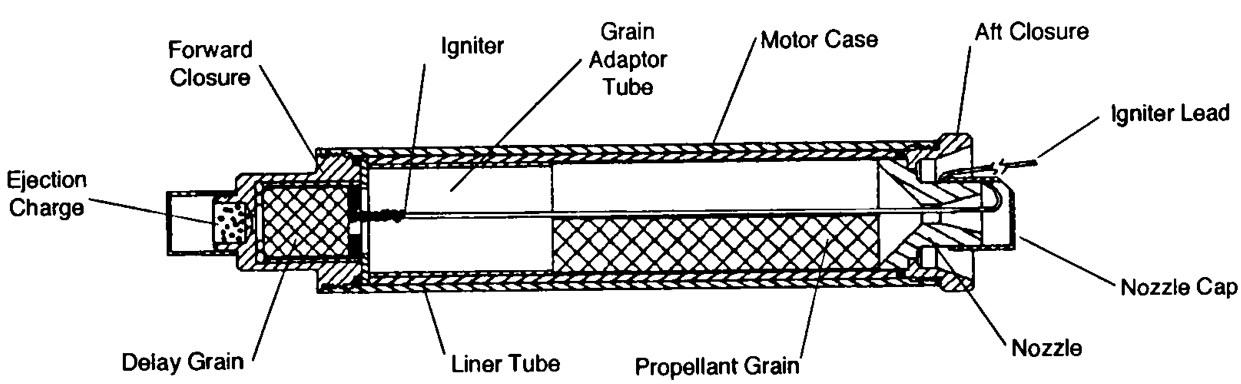
The propellant grain may be in two or more modules. It is normally enclosed in a cardboard or insulating tube from which it cannot be removed. The maximum weight of a reloadable solid-propellant grain is 62.5 ounces under NFPA 1122 "Code for Model Rocketry," and the NAR standards for certification of model rocket motor types.

Before first use, the reusable components are cleaned and readied for loading. After use, the interior of the motor casing is coated with carbon-like burned propellant residue that must be cleaned out by the user. Many model rocketeers enjoy the additional physical work required to reload a motor in the field.

Reloadable model rocket motors are normally available from Type D through Type G. Although smaller reloadable model rocket motors have been fabricated and tested, they are usually too small to be easily cleaned and reloaded.

Because the initial expense of such motors is much higher than expendables, they are mostly used by adults who fly a lot of model rockets. A model rocketeer must make an average of three flights with a reloadable model rocket motor before reaching the break-even cost point.

The major problem with reloadable model rocket motors was their departure from the basic paradigm



of model rocketry: the factory-made single-use model rocket motor that required no handling of propellant by the user. Over a decade of tests have shown that "reloadables" are as safe to store, handle, and use as "expendables."

Is the propellant sensitive?

Since 1957, sensitivity tests have been conducted. Model rocket motors have been pounded with a hammer; they wouldn't ignite or explode. Heavy weights were dropped on them, and nothing happened. Calculations made by a reputable national testing laboratory indicate that 4,634 foot-pounds of mechanical energy are required with 100% energy transfer to cause a black powder model rocket motor to ignite. This is equivalent to a 463-pound weight dropping from 10 feet so that the entire energy of impact is simultaneously absorbed by a single model rocket motor. More than a million foot-pounds of energy would be required to cause a full shipping case of model rocket motors to ignite. This is much greater than any impact that would be expected to occur during transportation even if the transporting vehicle were involved in a severe accident.

Tests were conducted in 1978 by the National Association of Rocketry during which a 22-pound weight was dropped 6.5 feet on both black powder and composite model rocket motors. These impacts totally destroyed the model rocket motors but did not cause them to ignite or explode.

Addtional tests have shown that model rocket motors are not susceptible to electrostatic ignition when electric sparks up to 14,000 volts are passed through the propellant grain.

Model rocket motors must not ignite spontaneously during extended exposure to temperaures up to 125°C (257°F).

Transportation and shipping accidents in which model rocket motors are involved must be reported to the Hazardous Materials Transportation Office of the U.S. Department of Transportation. About 500,000,000 model rocket motors have been shipped since 1958, and NO incidents of spontaneous ignition or explosion of model rocket motors from ANY cause have been thus reported.

Is model rocket motor propellant toxic?

Not really and it isn't very tasty, either. The black powder propellant grain of a solid propellant model rocket motor is very hard while composite solid propellant has the consistency of a rubber eraser. Several model rocket motors could probably be eaten with no ill effects. No illnesses have been reported that were caused by people eating model rocket motors. In fact, there are no reports of anyone trying to eat them. N. Irving Sax in his definitive work, *Dangerous Properties of Industrial Materials*, rates both potassium nitrate and ammonium perchlorate as "moderately toxic" and notes that small, repeated doses may lead to weakness, headache, and general depression. Potassium nitrate is also known as saltpeter and, along with carbon (charcoal) and sulfur, has been used historically for medicinal purposes. The NAR and model rocket manufacturers caution that people should not make a *habit* of eating model rocket motors.

Will it explode?

Since 1957, investigators of the National Association of Rocketry have tried to make model rocket motors explode deliberately by hitting them, throwing them in fires, burning them with welding torch, sawing them in half with high-speed band saws, shooting them with 30-caliber hunting rifles at short range, and otherwise mistreating them. The author and others have conducted carefully controlled tests in an attempt to make model rocket motors explode in order to determine the conditions that would cause them to explode. We haven't succeeded in achieving an explosion of a model rocket motor when subjected to experimental conditions designed to determine if, how, and why a model rocket motor would or could explode. We do know that a model rocket motor will ignite and burn under extreme conditions such as being directly exposed for a minute or more to a sustained fire such as the blue flame of an oxy-acetylene cutting torch.

Since 1957, the author has had only three "catastrophic failures" of model rocket motors in which the casing ruptured. One was a large Type F black powder motor that exploded at ignition in 1960 due to improper ignition technique. The other occurred in 1974 with a small mass-produced Type D black powder model rocket motor that had undergone day-night temperature cycling for several years in the Arizona desert environment where the maximum storage temperatures often reached more than 180^0 F and fell to about 20^0 F in the winter. In both cases, the motor manufacturer immediately withdrew the production lot from distribution, tested and determined the cause of the failure, and then corrected the problem. The third incident occurred under safe conditions on a model rocket flying site.

What happens when a model rocket motor accidentally explodes?

Model rocket motors are designed and manufactured under the standards of NFPA 1122 Code for Model Rocketry that requires any explosive failure result in motor components being expelled from the motor casing in a longitudinal direction — i.e., along the center line of the motor forward or backward. Given that millions of model rocket motors are manufactured every year and that one out of 280,000 could statistically fail, NFPA 1122 Code for Model Rocketry and the NAR's Model Rocket Safety Code require that all people remain at least 15 feet away from any model rocket motor or cluster of model rocket motors having a combined total impulse up to 30 Newton-seconds (a mid-range Type E motor) and 30 feet from all model rocket motors exceeding this power limit. (The total impulse of every model rocket motor type is known and published; it must be within plus-or-minus 20% of the mean value established for that motor type.) This distance provides an adequate safety margin should a model rocket motor undergo a catastrophic failure.

When a motor failure occurs, it is usually caused by internal overpressure created by the separation of the propellant grain from the casing. It may also be caused by a void in the grain or incomplete compaction during manufacture. These factors create an increased internal combustion pressure. When this occurs, the "fail safe" design of the model rocket motor causes either the nozzle to blow out the rear or the internal components of the motors to be blown forward into the model rocket body. As mentioned above, model rocket motor casings rarely fail. Hydrostatic tests of paper model rocket motor casings have been made to a pressure of 1,000 pounds-per-square-inch without rupturing. Casings used in composite model rocket motors are designed to withstand internal pressures 2.0 times normal maximum design operating pressures.

Is the exhaust gas toxic?

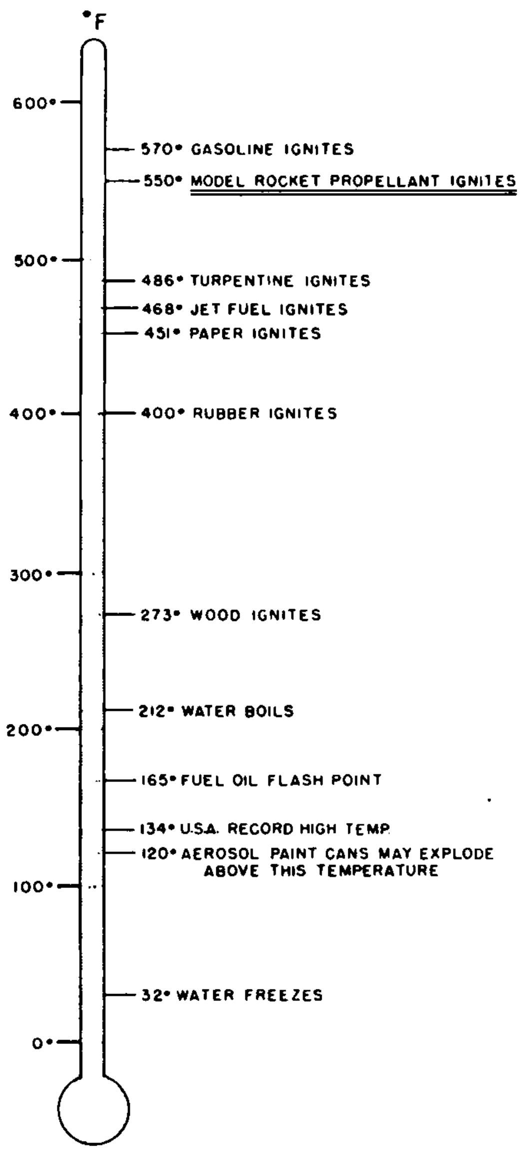
The exhaust gas resulting from the operation of a model rocket motor has not been shown to be toxic in the quantities produced by a model rocket motor. Sax lists as "slight toxicity" the ammonium carbonate solid residue cause by the operation of a black powder rocket motor and as "variable" the potassium sulfide and potassium sulfocyanate solid residues. The gas produced by a composite solid propellant rocket motor is not toxic in the quantities produced by the operation of the largest permissible model rocket motor containing 62.5 grams (2.2 ounces) of propellant. However, when burning, composite propellants produce HCl which, if the motor is operated in an enclosed space, can reach toxic levels.

Does a model rocket motor produce a flame while operating?

No. All combustion of the solid propellant takes place inside the casing. In black powder model rocket motors, the jet is a plume of luminous gas approximately 9 inches long for Type D motors. This glowing plume is caused by the high temperature of the exhaust gas and the luminous microscopic solid products of the internal combustion process. The exhaust plume is similar to the glowing gas plume seen coming from the exhaust pipes of high-performance racing cars.

Does a model rocket motor casing get hot?

In accordance with the national standards set forth in NFPA 1122 Code for Model Rocketry, a model rocket motor type cannot be certified for sale and use in the United States if the external temperature of its motor casing exceeds 200° C (392° F) during or after operation. In a model rocket airframe, the model rocket motor is retained and centered by paper and plastic parts. Paper ignites at 452° F and nylon suffers heat distortion at 400° F. Most paper-cased model rocket motors could be held in a bare hand while operating, but this practice is not encouraged in model rocketry.



What will the exhaust jet do?

In 1970, the author conducted a series of tests to find out. The jet from a typical 18x70-millimeter black powder model rocket motor (a standard size) did not burn a hole through a single sheet of 20-pound white typewriter paper when the jet was directed perpendicularly against the paper at a distance of 12 inches. At a distance of 6 inches, the jet punched a hole through the paper about 1¼ inches in diameter that was self-extinguishing.

Will the exhaust jet cause a burn?

If a someone's fingers are in the jet, they will be burned. This is why specific instructions for the safe and reliable electrical ignition of all model rocket motors are provided in each package of replacement motors. If a person gets burned by a model rocket motor, it happened because instructions were not followed, pre-launch tests were not conducted per instructions, or the product was being misused in direct disregard of all safety rules, common sense, and instructions.

How is such a burn treated if one occurs?

A burn from a model rocket motor jet exhaust should be treated like any other burn. Get the burned area immersed in ice water or cold water was quickly as possible. See a physician immediately. None of the exhaust products are poisonous.

Can a model rocket motor be ignited with a match?

Since 1957, the author and others have tried to do this. During tests conducted by Estes Industries, Inc. in 1966, a Type B3-7 black powder model rocket motor was held vertically, nozzle down, ¼-inch above the flame of a 1½-inch diameter paraffin candle. It did not ignite after 60 seconds of exposure. The paper casing began to smolder but self-extinguished 2 minutes after the candle flame was removed.

Can a model rocket motor be ignited with a fuse?

Although common "green" safety fuse will fit up the nozzle of some model rocket motors, it is difficult, unsafe, and unreliable to attempt ignition of a model rocket motor with a fuse. It is also contrary to the provisions of NFPA 1122 Code the Model Rocketry which forms the basis for laws in all 50 states. NFPA 1122 also prohibits the sale of fuse for igniting model rocket motors.

Under what conditions will a model rocket motor ignite?

The results of various fire immersion tests and flame application tests conducted since 1958 show that a model rocket motor will not undergo spontaneous ignition in a fire unless, literally, the "barn is burning down." A model rocket motor will ignite only if the temperature of the surface of its propellant grain reaches 550^0 F. Numerous burn tests of various black powder and composite model rocket motors and composite reloading kits conducted in 1958, 1966, 1978, and 1992 have confirmed this. Autoignition occurs only if a fire burns away a portion of the paper or plastic motor casing to expose the propellant grain itself to the fire. This is because the model rocket motor casing is an excellent insulator and because a bubble of insulating air becomes trapped in either the nozzle or the forward end of the motor, preventing hot particles or flame from getting into the motor casing and to the surface of the propellant grain. The amount of time required for a fire to burn through a model rocket motor casing varies from 30 seconds when subjected to the intense flame of an oxy-acetylene torch to 3-5 minutes during immersion in an intense wood fire.

Can model rocket motors be mailed?

Yes. Permission was originally received to mail model rocket motors on April 2, 1958. Currently, packages of model rocket motors weighing up to 25 pounds may be mailed. No incidents of fire or explosion have occurred as a result of mailing millions of model rocket motors. (See appended letter.)

Where are model rocket motors sold?

The majority of the nearly 500 million model rocket motors used since 1958 have been sold in hobby stores or in the hobby sections of department or discount stores.

Are model rocket motors "fireworks?"

The U.S. Department of Transportation, the Consumer Product Safety Commission, and the National Fire Protection Association consider model rocket motors to be propulsion devices for aeromodels and *not* fireworks.

The Research and Special Projects Administration of the U.S. Department of Transportation classifies model rocket motors as U.N. Classification Code 1.4S, Model Rocket Motors, NA0323, under the provisions of Section 173.56, Title 49, Code of Federal Regulations (49 CFR).

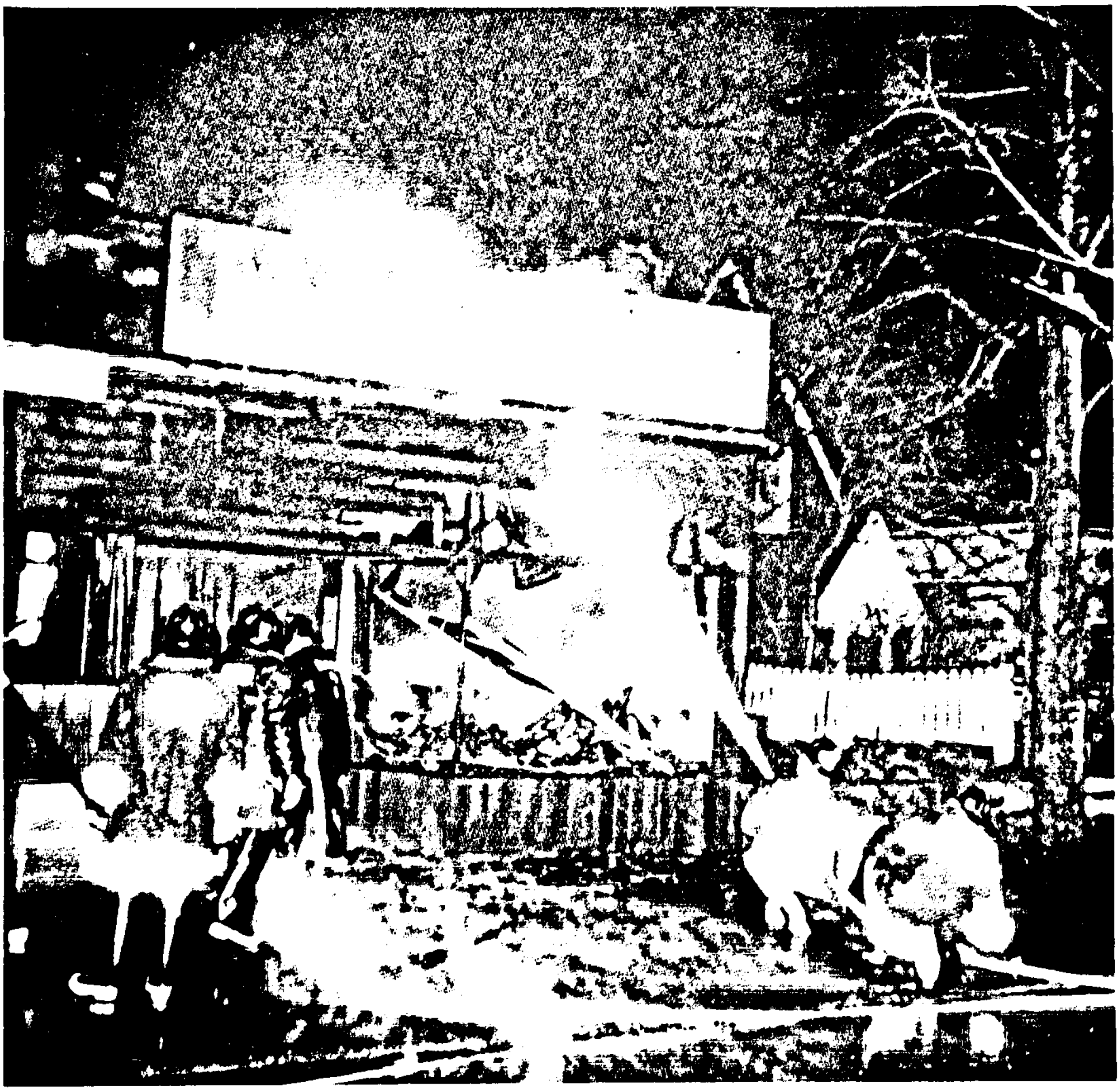
The National Fire Protection Association (NFPA) has a separate code for model rocketry, NFPA 1122 Code for Model Rocketry. The NFPA has specifically exempted model rockets and model rocket motors from consideration as fireworks under NFPA 1123, 1124, and 1126 having to do with the manufacture and use of Class B and Class C fireworks. The NFPA Technical Committee on Pyrotechnics has reviewed NFPA 1122 regularly since its inception as NFPA 41L-T in May 1967 and continues to treat model rockets and model rocket motors separately from all forms of fireworks.

A precedent-setting legal case regarding model rocket motors and fireworks is the Long Island, New York, hobby shop owner who was cited and tried for selling model rocket motors in violation of the New York state fireworks law., Section 270.00. He was acquitted. Reference: People v. Bochter, 1970, 63 Misc. 2d, 219, 211 N.Y.S. 2d 186.

Are model rocket motors a fire hazard?

On February 24, 1970, Toby's Hobby Center on the Post Road in Darien, Connecticut, caught fire and burned to the ground. All of the model rocket motors stored in their shipping packages on the shelves were later retrieved; none had ignited in the conflagration. (See photo.)

Experience has clearly shown that model rocket motors will not significantly contribute to a fire and are less of a fire hazard than other items available and sold in hobby and hardware stores — aerosol paint cans, model airplane fuel, model airplane glue, butyrate dopes in cans and bottles, and other cements and solvents.



PART THREE

TECHNICAL DETAILS OF THE MODEL ROCKET MOTOR

This Part goes into the scientific and technical details of both black powder and composite solid propellant model rocket motors. Its purpose is to reveal the scientific background supporting the contention that model rocketry is a technically-based hobby and recreation making use of the technology, practices, and methodology of full-scale astronautics and professional rocketry.

Internal ballistics, black powder model rocket motors.

A typical black powder model rocket motor is considered. 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 are assumed to behave as an ideal gas because the solid particles in the exhaust plume are assumed to be less than 0.0001 inches in diameter and thus have no effect on the thermodynamic processes of the exhaust gas. Insofar as possible, calculated results have been checked against measured test results with excellent agreement well within measurement tolerances.

Propellant: Black powder consisting of 74% KNO_3 as an oxidizer and a combination of 15.6% C and 10.4% S as a fuel plus binder. All percentages are by weight.

Delivered specific impulse (I_{sp}): 82 lb_f-sec/lb_m

Exhaust velocity: 2,650 ft/sec

Molecular weight of exhaust gas: 34.75 gm_m/mole

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 @ 106 psia

Burning area ratio: 19.7

Ignition temperature: 550° F @ 14.7 psia

Chamber temperature: 2,300° F

Throat temperature: 895° F

Exit nozzle temperature: 540° F

Chamber pressure: 106 psia

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

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 volume: 44.4% K_2CO_3; 20.5% K_2SO_4; 25.8% $K_2S_2O_3$; 3.7% K_2S; 0.5% S; 3.3% KCSN; 1.6% $(NH_4)_2CO_3$; 0.2% C

Chemical equation of combustion reaction: $74\ KNO_3 + 96\ C + 30\ S + 16\ H_2O \rightarrow 35\ N_2(g) + 56\ CO_2(g) + 3\ CH_4(g) + 2\ H_2S(g) + 19\ K_2CO_3(s) + 7\ K_2SO_4(s) + K_2S(s) + 8\ K_2S_2O_3(s) + 2\ KCSN(s) + (NH_4)_2CO_3(s) + S(s)$

Internal ballistics, composite solid propellant model rocket motors

A typical composite model rocket motor is considered. Data was determined with the assumptions that the combustion process is adiabatic and isentropic, is in frozen equilibrium, and is complete. It is assumed that 100% of the exhaust products are gaseous. It is also assumed that the nozzle exit pressure is 14.7 pounds-per-square-inch absolute. Insofar as possible, calculated results have been checked against measured test results with excellent agreement well within measurement tolerances. Precise formulation of composite propellants varies, depending upon requirements for burn rate and other performance factors. Numerous types of elastomers can be used as both a fuel and a binder. Therefore, a range of parameters is shown.

Propellant: Composite solid propellant consisting of approximately 82% ammonium perchlorate NH_4ClO_4, 18% elastomers such as synthetic rubber, and less than approximately 1% stabilizers, burn rate enhancers, etc..

Delivered specific impulse (I_{sp}): 190 to 220 lb_f-sec/lb_m

Exhaust velocity: 6,112 to 7,077 ft/sec

Molecular weight of exhaust gas: approximately 23.7 gm_m/mole

Ratio of specific heats of exhaust: k = 1.25

Nozzle area ratio: 2.5 to 6.0

Propellant density: 0.058 to 0.076 lb_m/in^3

Propellant burning rate: 0.15 to 0.50 in/sec @ 1,000 psia

Burning area ratio: 82 to 400

Ignition temperature: 550° F

Chamber temperature: 4,283° F

Throat temperature: 3,831° F

Exit nozzle temperature: 1,982° F

Chamber pressure: 500 psia

Gaseous exhaust products: CO, CO_2, H_2, N_2, HCl

Chemical equation of combustion reaction: 21 NH_4ClO_4 + 10 $(C_4H_6)_n$ $\rightarrow$ 21 HCl + 10.5 N_2 + 34.5 H_2 + 27 H_2O + 23 CO + 17 CO_2 (Generalized equation; the C_4H_6 represents the long-chain organic molecules present in the elastomer/binder.)

Standards:

All model rocket motors produced for sale and use in the United States are manufactured in strict accordance with the standards established in NFPA 1122 Code for Model Rocketry and NFPA 1125 Manufacture of Model and High Power Rocket Motors.

Testing and Certification:

Before a model rocket motor type can be shipped in the United States, samples are tested and evaluated by the Bureau of Explosives of the Association of American Railroads. On the basis of these laboratory tests, the Research and Special Programs Administration of the U.S. Department of Transportation has assigned to model rocket motors the shipping classification "Model Rocket Motor," DOT Number NA0323, U.N. Classification Code Explosives 1.4S in accordance with Section 173.56, Title 49, Code of Federal Regulations (49 CFR). Up to 25 pounds of model rocket motors may be shipped in a single carton.

In accordance with NFPA 1122 Code for Model Rocketry, the National Association of Rocketry tests and certifies all model rocket motors sold and used in the United States, assuring that each motor type conforms to the standards set forth in NFPA 1122 Code for Model Rocketry. These also require each manufacturer to perform static performance tests on a random sample of 1% of each production lot. This helps keep random failures at an extremely low level.

This also means that about 5,000,000 model rocket motor static tests have been conducted since 1958 by model rocket manufacturers to ensure quality of performance and adherance to safety standards. Assuming that the average model rocket motor is Type B containing 0.25 ounces of propellant, this means that more than 39 tons of rocket propellant have been expended just for testing.

Statistical analysis indicates that the random failure rate of model rocket motors is one in 280,000 for *each ignition* with a confidence factor of 95%. This is *five times better* than the failure rate allowed by the Federal Aviation Administration for pressurized cabins of jet airliners and many times better than the failure rate demanded by the U.S. Department of Defense and NASA for solid propellant rocket motors used in large military missiles and space launch vehicles.

The design standards and materials for model rocket motors actually make catastrophic failure a non-problem. The launch stand-off distance was carefully determined to ensure that paper casing confetti or plastic casing pieces do not reach and hurt bystanders. Metallic cased reloadable motors are required to be non-fragmenting.

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PART FOUR

SUMMARY OF FORTY YEARS OF TESTING

Preface

Since 1957, controlled tests and careful analyses have been conducted to determine the "edge of the envelope" for model rocket motors and model rocket flight safety. These tests have been conducted for a variety of reasons.

Initially, the public and safety officials perceived all rockets as being dangerous because of the early, spectacular, and highly publicized failures of rockets in the United States space program. Author Tom Wolfe unfairly characterized this perception in his book, *The Right Stuff*, in which he wrote, "All our rockets blow up and our boys always botch it." However, it isn't generally known nor is it reported in the news media that since 1957 more than 96% of all space launches have been successful. This is an amazing track record because space rockets must have high performance capabilities and carry large quantities of high-energy propellants. Their technology literally "pushes the state of the art" at all times. On the other hand, model rocket manufacturers and hobbyists accepted reasonable limits of power and weight, never trying to push the state of the art but relying on proven and well-understood rocket propulsion technology that may be "old hat" to NASA but is perfectly adequate for recreational and educational purposes.

Secondly, the personal experience of most people, including public safety officials, was related to common fireworks such as skyrockets and bottle rockets. These are based on very old "low technology" and have an exhibited reputation for unreliability. Because of their unpredictability and their pyrotechnic payloads consisting of stars or firecrackers, these types of fireworks have indeed started many fires and caused many personal injuries. Nearly all manufacturers of fireworks skyrockets — most of them are in the Orient — use extremely primitive quality control procedures (if they have them at all) and almost no real understanding of the technology or critical design parameters of their products. They make fireworks the same way their grandfathers taught them, and those grandfathers were in turn taught by their grandfathers. Thus, the fireworks industry is largely based on empirical understanding at best, and new products are designed by the "cut-and-try" method with little real scientific or technical background. The testing procedures of most fireworks manufacturers are either non-existent or ludicrous in comparison to what they could be with modern chemistry and instrumentation. Answering an interrogatory in a fireworks injury case for which the author was a consultant for the plaintiff, an Asian skyrocket manufacturer described his company's quality control procedures as follows: "When we think a change occurs in our production, we take a skyrocket and fly it; if it flies, we sell the shipment." Although the size and amount of propellant in skyrockets and bottle rockets are now strictly limited by the Consumer Product Safety Commission, skyrockets continue to contribute to many personal injuries every year. Fireworks exhibit none of the high reliability, careful design, and thorough testing that have become the legacy of model rocketry.

In 1996, the Peoples' Republic of China began to consider the possibility of banning the use of fireworks by the public in that country because of the increasing number of injuries and the subsequent increase in costs of medical treatment.

Another important reason was that those of us who started model rocketry and those who continue to be involved in it at all levels as manufacturers and consumers want model rocketry to be as safe as practical. The hobby was started in 1957 to halt the carnage of people being hurt trying to make and fly their own rockets. The best way to achieve this goal is to determine by thorough testing what is safe, how far the technology can be pushed before products are no longer safe, and what are the realistic probabilities that a given product or operation may malfunction in such a way that it may become hazardous, and what the realistic consequences of this might be. Equally important was to learn first-hand what would likely happen if a model rocket or model rocket motor were used in the wrong way or misused. Over the decades, NAR and the manufacturers have learned that what is safe is not a matter of opinion; it can be determined by careful testing.

As a result, a continuing series of product tests goes on, often repeating earlier tests. To reproduce all of these lengthy and comprehensive reports in their entirety would not add to the validity of this document. Instead, Part Four will summarize the conduct and results of the tests that have been carried out since 1957.

Early tests, 1957 to 1960

The author began testing model rocket motors to determine their potential levels of hazard in February 1957. The result of these tests were documented in "Technical Report No. 1," dated June 1, 1958. The report was prepared by the author while he was President and Chief Engineer of Model Missiles, Inc., the first model rocket manufacturing company, in Denver, Colorado. Few copies of this report survive. However, the author has retained one in his archives and referred to it for this summary.

The model rocket motors used in those early tests were comparable in size, propellant type, and performance to model rocket motors of Type A and Type B presently being produced by several manufacturers. They were 18x70 millimeters in size, used black powder as a propellant, and featured a paper casing and a ceramic nozzle.

In February 1957, two model rocket motors were subjected to heat soak tests at 500° F for 2 hours. Spontaneous ignition did not occur. The motors performed normally 2 hours after removal from the oven.

Two model rocket motors were cold-soaked at -10° F for 72 hours and ignited while cold. Both units performed perfectly.

Shock sensitivity tests were also carried out. These may seem primitive today because of the highly instrumented tests that were performed later. In these early tests, two model rocket motors were forcefully thrown against a concrete wall. Spontaneous ignition did not occur and both units operated perfectly.

In January 1958, model rocket motors were subjected to three different flame tests. In the first, the flame from a blow torch was brought to bear on the forward end of a Type A black powder model rocket motor at a distance of approximately 6 inches. After 5 minutes had passed, the flame was removed. Slight charring of the motor casing was evident but the propellant did not ignite. In the second test, the blue flame of an oxy-acetylene torch was applied directly to the side of a model rocket motor casing midway between the ends. 30 seconds were required for the torch to burn through the paper casing and ignite the propellant. The resulting action was non-propulsive; no explosion occurred. Bonfire tests were conducted using a wood fire into which Type A and Type B model rocket motors were thrown. No ignition occurred after 20 minutes has passed. Subsequent inspection showed that the paper casings had been charred. A package of 6 Type A model rocket motors was then subjected to this test; the packing box was destroyed but the model rocket motors were unharmed.

A shipping hazard test was conducted using a standard six-pack of Type A model rocket motors with the instruction sheet, igniters, and all paper parachute system protection papers enclosed. A single model rocket motor in the middle of the package was armed with an electrical igniter and deliberately ignited. The exhaust jet burned a hole approximately 3/8-inch in diameter through the box but did not set the box afire or ignite the other 5 model rocket motors in the box.

A still-used standard safety demonstration involves setting the model rocket launch pad atop a sheet of clean, white 20-pound typewriter paper and then launching a model rocket from the pad. There is never any evidence of charring or ignition of the paper.

The Estes Tests, 1966

Vernon D. Estes, then President of Estes Industries, Inc. in Penrose, Colorado, conducted a series of potential hazard and autoignition tests in 1966. These tests and their results were documented in a report with photographs, "Youth Rocket Safety." Here is a summary of those tests.

A .303 Savage rifle was used to fire a bullet directly into a Type C black powder model rocket motor at a distance of about 20 feet. The impact of the bullet ripped the motor apart. No explosion occurred and the impact did not cause autoignition of the black powder propellant.

A high-speed band saw was used to cut directly through a Type B black powder model rocket motor. No ignition or explosion occurred during or after the test.

A 5-pound weight was dropped 20 feet onto a Type C black powder model rocket motor. The motor was destroyed by the impact. No ignition or explosion occurred.

The flame of a 1½-inch paraffin candle was applied to the nozzle and the forward end of a Type C black powder model rocket motor held in both the vertical and the horizontal position. The flame exposure direction was 13 seconds in the horizontal mode and 11 seconds in the vertical mode. No ignition of explosion occurred in either test. To determine the "edge of the envelope," the vertical flame exposure tests was run for 60 seconds at which time the paper motor casing began to burn but, upon removal of the candle flame, was self-extinguishing although it continued to smolder for 2 minutes. No ignition or explosion occurred.

Five individual Type B and Type C model rocket motors plus a package of three of these motors were placed in a fire fueled by crumpled newsprint. The fire went out once the newsprint was consumed. None of the model rocket motors ignited or exploded.

A Type C6-0 was placed in a vertical, nozzle-down position and a lighted cigarette was snuffed out against the exposed forward end o the propellant grain. No ignition or explosion occurred.

A Type C6-0 model rocket motor was laid on asphalt pavement saturated with gasoline and the gasoline was ignited. The fire burned itself out after 2 minutes without igniting the motor.

A sustained fire of 1-inch by 6-inch balsa blocks was constructed. 12 Type B and Type C black powder model rocket motors were placed randomly in the fire material. 3 minutes after the fire started, a single Type C6-0 model rocket motor ignited at its forward end and was non-propulsive. At 4:45 into the test, 11 of the 12 motors had ignited. All motors remained within 3 feet of the fire after ignition. None of the model rocket motors exploded.

The MPC Tests, 1970:

In May-June 1970, the author conducted a series of safety tests of model rocket motors for Model Products Corporation, then a subsidiary of General Mills, Inc. The results were reported in "Model Rocket Safety: A Technical Report," published by MPC in Mount Clemens, Michigan in August 1970. The report was endorsed by the Hobby Industry Association. MPC black powder model rocket motors used in the tests were identical in all respects to those produced by Estes Industries, Inc.

On May 12, 1970, the following tests were conducted in Madison, Wisconsin: hammer blow, bullet impact, band saw cutting, gasoline fire immersion, and oxy-acetylene torch.

A Type B black powder model rocket motor on a concrete slab was struck forcibly with a 16-ounce claw hammer. The motor was destroyed. There was no ignition or explosion.

A 70-grain soft-point bullet from a 30-30 Winchester rifle was fired against a Type B black powder model rocket motor from a distance of 25 feet. The bullet struck the motor at the interface between the propellant grain and the time delay. The paper casing was ruptured by the bullet impact. Approximately 75% of the propellant remained intact; the remainder was scattered by the force of the impact. No ignition or explosion occurred.

A Type C black powder model rocket motor was sawed completely in half through its diameter by a Do-All band saw in 45 seconds with no ignition or explosion of the propellant.

Two Type B black powder model rocket motors were placed on sandy ground soaked with approximately one pint of gasoline. The gasoline was ignited with a match and burned for approximately 5 minutes. The two model rocket motors did not ignite or explode. The outer layer of each motor's paper casing was charred or sooty and could be scraped clean with a pocket knife blade. Both motors then operated according to specification.

A Type B black powder model rocket motor was clamped vertically and nozzle-up in a bench vise. The blue flame of an oxy-acetylene cutting torch was applied to the side of the motor casing approximately halfway along the casing. 31 seconds into the test, the flame had burned through the casing to the propellant which ignited and burned with a jet projected radially outward from the motor casing. No explosion occurred.

On May 14, 1970, the following tests were conducted in New Canaan, Connecticut:
paper fire, sustained fire, and exhaust impingement.

Two sheets of newsprint were crumpled into a loose wad. Two Type B black powder model rocket motors were placed atop the wad which was ignited by a match. The fire died after 3 minutes. Neither model rocket motor ignited or exploded. The paper casings were slightly browned and scorched, but both motors were usable.

A rick-type fire was built using pieces of green pine ½ to 1 inches square and 9½ inches long. A sheet of crumpled newsprint was placed under this rick as tinder and starter. Two Type B black powder model rocket motors were placed atop the rick where they would be exposed to the greatest flame and heat. The fire blazed strongly, creating a bed of red-hot coals. One motor ignited at 5 minutes and propelled itself 6 feet from the fire. A few seconds later, the second motor ignited, propelling itself 3 feet from the fire. Subsequent examination of the motors revealed that the fire had burned its way through the paper casings roughly halfway along their lengths, thereby igniting the propellant grain when it became exposed to the fire.

For the exhaust impingement tests, a wooden frame was erected to support a single sheet of 8½-inch by 11-inch 20-pound white mimeo bond paper. A bench vise was used to hold a black powder model rocket motor in a horizontal position at varying measured distances from the paper. Type A black powder model rocket motors were used in this test. The exhaust jet was directed perpendicularly at the sheet of paper. Tests were conducted with the exhaust nozzle at a distance of 36, 24, 18, 12, 9, and 6 inches from the paper. At distances from 36 to 12 inches, the jet did not burn the paper. At a distance of 9 inches, photos revealed that the tip of the luminous exhaust jet just touched the paper; a ragged self-extinguishing hole with charred edges was burned through the paper. At a distance of 6 inches, the jet literally punched a hole through the paper approximately 1¼-inches in diameter. The charred edges of the hole were self-extinguishing.

The Phoenix Fire Tests, 1971:

In May 1971, the research staff at Centuri Engineering Company, a model rocket manufacturer, conducted a model rocket fire test with help from the officials of the Phoenix (Arizona) Fire Department. A large-scale hobby shop fire was simulated inside a large, special concrete fireproof building supplied by the Phoenix Fire Department. A loaded store counter was doused with gasoline and set afire. No attempt was made to extinguish the blaze. The test simulated a large-scale hobby store fire with model rocket motors on the shelves. Its purpose was to determine how many, if any, model rocket motors in their store packaging would survive the fire. Data from this test are understandably skimpy because it was conducted in a special fireproof building without the benefit of observers to see what happened. As in the actual Darien, Connecticut, hobby shop fire, a large number of model rocket motors did not ignite. No motors exploded.

The Alhambra (California) Simulated Hobby Shop Fire Test, 1972:

Another similar test was conducted on January 24, 1972 by the City of Alhambra, California in cooperation with other municipal fire departments and the Office of the California State Fire Marshal. The purpose of the test was to determine and compare the hazards in a fire of confined model rocket motors with those on an open shelf. (See test report appended.) Within 2 minutes, aerosol paint cans began to explode or were propelled as far as 130 feet from the fire center. After 3 minutes, cans of model airplane fuel burst their containers and created balls of fire 4 to 5 feet in diameter. Model rocket motors did not ignite until 4 minutes into the fire, some of them traveling 20 to 50 feet from the fire center.

The Truesdail Laboratory Tests, 1977:

In September 1977, tests were conducted by Truesdail Laboratories, Inc. in Los Angeles, California to determine the autoignition temperatures of black powder model rocket motors. The test report is appended. The autoignition temperature tests showed that 99.7% of all black powder model rocket motors would have an autoignition temperature between 541° F and 637° F (3-sigma boundary). The amount of mechanical energy in the form of physical shock required to raise the temperature of a black powder model rocket motor to the autoignition temperature, assuming that the impact energy is totally absorbed over the whole mass of the model rocket motor, was calculated to be 4,634 foot-pounds. This is equivalent to a 463-pound weight dropping a distance of 10 feet such that the entire impact would occur on a single model rocket motor.

The NAR-HIA Las Vegas Tests, 1978:

In response to a request from the Hazardous Materials Transportation Branch of the U. S. Department of Transportation, the National Association of Rocketry (NAR) and the Model Rocket Division of the Hobby Industry Association (HIA) conducted a series of tests near Las Vegas, Nevada on September 30, 1978, to simulate the worst possible conditions to which large model rocket motors could be subjected in a major transportation accident. These tests utilized model rocket motors representing every propellant combination, casing material, and design, most of which are still available the time of this writing.

Three different types of black powder model rocket motors and two types of composite model rocket motors were provided by model rocket manufacturers and used in these tests. Propellant quantities per motor ranged from 25 to 80 grams for black powder model rocket motors and 54 to 57 grams for composite model rocket motors.

A test was conducted to simulate the crushing of a single loose model rocket motor in the crash of a transportation vehicle. The test device was a concrete-loaded steel cylinder weighing 22 pounds (10 kilograms) that could be remotely released to fall a distance of 6.2 feet (2 meters) onto a test motor that rested on an aluminum plate. Each type of test motor was impacted in two orientations: one with the impact being received with the motor upright, nozzle up, and the other with the motor resting on it side so the center of the falling weight impacted at the center of length of the motor. In the first orientation, 184 joules of energy (135.65 foot-pounds) were applied at impact. In the second orientation, 196 joules (144.5 foot-pounds) were applied. This was far less than the 4,634 foot-pounds required to cause auto-ignition of black powder model rocket motors; however, it was believed that this degree of jolt or impact most closely approximated what might be encountered in a shipping accident by all types of model rocket motors. No ignitions or explosions occurred.

Tests were conducted with each type of model rocket motor in a quantity and the packaging normally used by each manufacturer. A single motor in the center of a shipping carton was remotely ignited by an installed electrical igniter. No chain reactions of explosions resulted from the ignition of a single model rocket motor in a DOT 12B25 fiberboard carton. Additional ignitions of other motors in the carton occurred after considerable delay as a result of the burning of the carton itself. The propulsive behavior of the model rocket motors was generally confined to brief excursions at velocities estimated to be less than 150 feet per second.

Tests were conducted to determine the behavior of single unpackaged model rocket motors when subjected directly to a fire intense enough to ensure their destruction. A test fire was created using Presto-Lite pressed sawdust fireplace logs soaked in charcoal fire starting fluid. The fire became extremely hot and intense very quickly. Motor ejection charges ignited first, making the motors non-propulsive in their subsequent behavior. Ignition occurred from 35 seconds to 3 minutes 45 seconds after immersion of a motor in the fire. No explosions or dangerously propulsive behavior occurred.

A test was conducted to determine how a DOT 12B25 fiberboard carton loaded with model rocket motors would behave while being consumed in an intense fire, the time required for the fire to ignite the motors, and whether a carton of 216 model rocket motors weighing 25 pounds represented an unreasonable shipping hazard. Ignition of the first model rocket motor in the carton occurred 2 minutes 10 seconds after immersion in the fire. All ignition activity was complete after 11 minutes. No motors exploded. The behavior of the model rocket motors in these tests as essentially the same as observed in the Alhambra Simulated Hobby Shop Fire Tests in 1972.

The 1978 Las Vegas tests confirmed that the shipping and storage hazards of composite model rocket motors were no greater than those of black powder model rocket motors.

The consequence of the Las Vegas tests was the decision of the Hazardous Materials Transportation Branch of the U.S. Department of Transportation to allow packages of up to 25 pounds of model rocket motors to be shipped as "Flammable Solids" under DOT exemption 7887.

Since the issuance of DOT E-7887, there have been no incidents of any sort involving the shipment of model rocket motors of all types by all modes of transportation.

The NAR Blue Ribbon Commission Tests, 1983-1985:

In 1983, the NAR was aware that the technology of composite propellant model rocket motors had advanced to the point where model rocket motors of much greater power (total impulse) and model rockets of greater weight and size were possible. In fact, these larger and more powerful model rockets were being flown safely in many parts of the United States where public safety officials had been consulted and were cooperative.

The resulting NAR Blue Ribbon Commission on High Power Rocketry — of which the author was a member — conducted numerous studies and tests to investigate the many factors involved with increasing the historical weight and power limits that had served the hobby well for 25 years. After more than a year of study and testing, the Commission recommended an increase in the permissible gross weight of a model rocket from 1 pound to 3.3 pounds and an accompanying increase in the allowable total impulse of model rocket motors from 80 Newton-seconds (Type F motor) to 160 Newton-seconds (Type G motor). A number of studies and tests were conducted in connection with this work that are of interest in the matter of model rocket safety.

A thorough study was conducted by Lieutenant Commander Arthur H. Barber III, USN, and the author (a private pilot since 1946) concerning the potential hazard to aircraft of model rockets in flight. It was determined from hail impact research carried out decades ago by the National Advisory Committee on Aeronautics (NACA), the predecessor of NASA, that the impact of a model rocket weighing up to 3.3 pounds would have little effect on metal-skinned aircraft that comprised more than 99% of the aircraft flying. Furthermore, Federal Aviation Regulations (FAR 25.631) require that an airplane be capable of sustaining the impact of an 8-pound bird at cruising speed and continue to fly safely. FAR 33.77 requires that a jet engine be capable of ingesting a 4-pound bird, piece of tire tread, or broken helicopter rotor blade without catching fire, bursting, or losing the capability of being shut down. A jet engine must also be capable of ingesting a 1½-pound bird or mixed sand and gravel without losing more than 25% of its power. Furthermore, the final reports of the U.S. Army Ordnance Corps' Loki unguided fin-stabilized surface-to-air missile project conducted over a 10-year period prior to its termination in 1956 were located in unclassified Department of Defense archives. This report indicated that the normal dispersion of an unguided, fin-stabilized spinning rocket was so great that, even using a radar-directed launcher, a Loki rocket had an infinitismal chance of striking an aircraft. The author was involved with the Loki project at White Sands, New Mexico in the 1951-1953 time period. Loki became more of a joke than a serious threat to aircraft. Calculations made by the Flight Safety Branch at White Sands indicated that there was only one chance in 4 billion for each launch that an unguided, fin-stabilized, spinning rocket could hit an airplane. This Loki data was instrumental in the FAA's original 1961 decision to exempt model rockets from control and regulation.

A study of potential bodily injuries that might be caused by the impact of model rockets was undertaken by Dr. James Phillips, M.D., of Grand Prairie, Texas. A literature search was conducted to discover data on bullet and other projectile wounds by military personnel. This data was applied to model rocket impacts. Dr. Phillips pointed out that a velocity of 350 feet per second (238 miles per hour) is required for a .17-caliber air gun pellet to pierce the skin and would be higher for a model rocket. Baseballs travelling at 146 feet per second (100 miles per hour) will cause concussions or fracture of the facial bones. Because of the frontal area of a model rocket and its frangible materials plus the energy-absorbing capability of the human skull, Dr. Phillips is of the opinion that injuries would not be significant except if impact occurred in the vicinity of the eye socket. In the opinion of Dr. Phillips, it would require the direct impact of a properly-shaped one-pound rocket travelling at a speed of nearly 900 feet per second (616 miles per hour) to cause any serious injury to the human skull. Dr. Phillips had no data to allow him to determine whether or not such a high-speed model rocket would penetrate the human rib cage but believes the soft abdomen would be penetrated. He points out that increased velocity does not contribute most to potential injury. (The only serious bodily injury caused by a model rocket since 1957 was an eye impact of a model rocket descending at high speed because it had been constructed and operated contrary to instructions and safety rules.)

A study of potential weapon use of model rocket components was undertaken by Martin Huber, Department of Physics, Stanford University, Palo Alto, California, in conjunction with the NAR Blue Ribbon Commission tests. This analysis investigated the use of model rocket motors to make "bazookas" and "mortars." The results led to the voluntary adoption by the NAR and the model rocket manufacturers of limits to the average thrust of model rocket motors. This recommendation was quickly adopted into the 1987 version of NFPA 1122 Code for Model Rockets. Furthermore, Huber's analysis confirms and substantiates the U.S. Army Ordnance Corps' Loki anti-aircraft rocket data indicating that the probability of a model rocket hitting a designated target is infinitismally small: one chance in 14 billion for each launch with a 95% confidence level.

As a result of the findings of the NAR Blue Ribbon Commission, the NAR and the Hobby Industry Association petitioned the Federal Aviation Administration (FAA) in 1985 to increase the exempted model rocket weight limits to 1,500 grams (3.3 pounds). The FAA undertook its own internal study and hired an independent consulting contractor to verify the findings supporting the NAR-HIA petition. In 1993, the FAA amended the Federal Aviation Regulations Title 14 CFR Chapter I, Subchapter F, Part 101, Paragraph 101.1(a)(3)(ii) to allow the flying of 3.3-pound model rockets.

The Phoenix Burn Tests, 1992:

A series of burn tests was conducted on March 20, 1992 at the burn pad of Universal Propulsion Company, Phoenix, Arizona, under the auspices of the National Association of Rocketry. The objective was to repeat the 1978 Las Vegas burn tests, reconfirm the results, compare the behavior of model rocket motor reloading kits under similar test conditions, and assess the potential for accidental autoignition of model rocket motor reloading kits and components. These tests confirmed the Las Vegas test findings and showed no increased fire hazard attributable to existing model rocket motor reloading kits in comparison to those of expendable model rocket motors. Additional tests were conducted with the hot coals of burning cigarettes applied directly against the raw composite propellant grains of a reloading kit, glowing cigarette ashes being flicked against raw propellant grains, and the actually snuffing-out of a lit cigarette against the exposed end of a propellant grain. (No ignition took place during these cigarette tests intended to simulate "worst case" exposures to potential ignition in the marketplace and flying field.)

The M.I.T. Burn Tests, 1992:

On March 28, 1992, members of the Standards & Testing Committee of the National Association of Rocketry conducted similar ignition tests of reloadable model rocket motor propellant modules at the Massachusetts Institute of Technology, Cambridge, Massachusetts. These tests were conducted independently of the Phoenix burn tests and without knowledge of the Phoenix test results. Ignition sources were high-voltage electric arcs and burning cigarettes. The M.I.T. test results confirmed the findings of the Phoenix burn tests.

The Barber Report, 1994:

Between August 14, 1993 and April 4, 1994, the results of all these tests were compared and additional autoignition tests, product mis-use tests, and other investigations deemed potentially significant were carried out under the supervision of Captain Arthur H. Barber III, USN, at the Aeronautics Laboratory of M.I.T. in conjunction with the NAR Standards and Testing Committee at the request of J. Patrick Miller, then President of the National Association of Rocketry. CAPT Barber carried out the work as an unpaid volunteer with no affiliation with any model rocket manufacturer and on his own time separately from his career as a naval officer. His study had four objectives: (1) identify any and all real or perceived safety issues with metal-cased reloadable model rocket motors, (2) determine if all such issues had been considered with the appropriate thoroughness and technical rigor by previous studies and testing, (3) investigate any "residual" issues that appear not yet to have been exhaustively addressed and conduct testing as appropriate, and (4) recommend whatever changes to the NFPA codes and NAR motor certification procedures were needed to ensure that current and future model rocket motors are safe for consumer use. During this study, CAPT Barber also researched potential issues in the professional engineering literature. This study showed that model rocket motors, including reladable motors, currently on the market are sufficiently well-designed so it is very difficult to make them hazardous even with deliberate and intelligent misuse. Another outcome of the study was a revision to the motor certification standards in NFPA 1122 Code for Model Rocketry to further ensure that motors certified under these standards are safe under every reasonable condition of handling, use, and various types of misuse that could occur when well-intentioned consumers fail to read or follow the instructions provided with these products.

Summary:

The many studies and tests carried out under carefully controlled conditions by knowledgeable people having scientific and technical education, training, and backgrounds serve to confirm and reinforce the actual fact that model rocketry is one of the safest hobbies, sports, and recreations. These studies and tests provide the data necessary to understand the outstanding safety record of model rocketry since 1957 with about 500 million model rocket flights. This has come about because of careful product design and modern quality control procedures, plus an early application of the principles of ergonomics (the person-machine interface) and simple psychology. These studies and tests have confirmed and reconfirmed the facts that model rockets and model rocket motors do not pose a fire or explosion hazard in shipment, storage, and use and that they can be operated with a high degree of safety to persons and property provided instructions and common-sense safety rules are followed.

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PART FIVE

THE REGULATORY ENVIRONMENT

Preface:

Various organizations and agencies and their codes and regulations are discussed in this part.

Since 1957, the operating policy of the National Association of Rocketry has been the control of the hobby of model rocketry at the manufacturing level rather than at the consumer level. Decades of experience have now shown this to be the proper and safe policy. Originally, some jurisdictions required permits to sell, purchase, or use model rocket motors. However, as the safety record of no-permit or "open" jurisdictions grew and was compared with that of the permit environments, there was no evidence that the permit environments were safer. In fact, there were indications that the permit environments tended to force some enthusiasts to attempt to build their own rocket motors. Therefore, with few exceptions, most states and local jurisdictions today no longer have permit requirements of any sort because they have learned that the "regulation at the source for safety" policy is workable.

The hobby of model rocketry has also had a long-standing history of self-policing itself with the philosophy that if the manufacturers and consumers don't, someone else may step in to do it in a way that neither will like.

The National Association of Rocketry (NAR), a non-profit 501(c)(3) corporation founded in 1957 in Colorado, maintains a Joint Manufacturers/ Association Council (JMAC) which meets when necessary to coordinate efforts with the manufacturers. The NAR and most model rocket manufacturers are represented on the Technical Committee on Pyrotechnics of the National Fire Protection Association (NFPA).

The National Fire Protection Association

The primary national voluntary standards-making organization for public safety in the United States and Canada is the National Fire Protection Association (NFPA), Batterymarch Park, Quincy, Massachusetts 02269. Through its Standards Council and its various Technical Committees, NFPA publishes recommended safety codes, most of which are adopted outright by reference in most states by virtue of enabling legislation. The NFPA developed and publishes the National Electrical Code, the Fire Prevention Code, and the Life Safety Code. All NFPA codes containing standards are adopted by the American National Standards Institute (ANSI).

In 1965, the NFPA Standards Council instructed the Technical Committee on Pyrotechnics to develop a code for model rocketry. With the help of the NAR, NFPA 41L Code for Model Rocketry was adopted by NFPA in 1968. In 1976, the code was renumbered NFPA 1122. It has been continually reviewed, updated, and revised by the Technical Committee on Pyrotechnics at least every 5 years. NFPA 1122 Code for Model Rocketry has been adopted either outright or in modified format by all 50 states. NFPA 1122 specifically exempts model rockets and model rocket motors from consideration as fireworks. This distinction between model rockets and fireworks is maintained in all NFPA codes have to do with explosives and pyrotechnics.

A copy of NFPA 1122 Code for Model Rocketry and NFPA 1125 Manufacture of Model and High Power Rocket Motors may be obtained from the National Fire Protection Association, Batterymarch Park, Quincy MA 02269.

The basic NFPA policy concerning model rockets is stated in the Foreword to NFPA 1122:

"The NFPA Technical Committee on Pyrotechnics believes that this code contains appropriate measures to safeguard this popular and growing activity. Safe model rocket activities should not be confused with the hazardous, uncontrolled operations of so-called basement bombers and amateur rocketeers who attempt to make their own propellants, rocket motors, and large metallic rocket vehicles. Model rocket activities should be allowed within the specifications of this code to guide our science-minded youth and citizens safely."

The U.S. Department of Transportation

The Research and Special Programs Administration of the U.S. Department of Transportation (DOT) has the authority under the Code of Federal Regulations (CFR 49) to regulate the transportation of all hazardous materials such as gasoline and other substances that may be flammable, explosive, or toxic.

The first step in compliance with CFR 49 is for a manufacturer to obtain classification of a product by means of tests conducted by the Bureau of Explosives of the Association of American Railroads or other testing laboratory recognized by the DOT. The first model rocket motors produced in 1957 were given the classification, "Toy Propellant Devices." Today, model rocket motors are shipped under U.N. classification Code Explosive 1.4S with the proper shipping name and number "Model Rocket Motor, NA0323." Because of tests conducted by the NAR, and described in this document, model rocket motors may be shipped in fiberboard cartons weighing up to 25 pounds and are acceptable for transportation by all carriers including passenger-carrying aircraft.

The Bureau of Alcohol, Tobacco, and Firearms

The Bureau of Alcohol, Tobacco, and Firearms does not require low-explosive user permits or storage magazines for model rocket motors containing less than 62.5 grams (2.2 ounces) of propellant.

The Federal Aviation Administration

In 1961, the NAR worked with the Federal Aviation Administration (FAA) in developing regulations relating to the flight of model rockets. The FAA exempts model rockets weighing less than 1 pound (456 grams) propelled by less than 4 ounces of slow burning rocket propellant provided the models are made from paper, plastic, or wood. In 1993, the FAA further extended its exemption limits by revising their regulations to permit the flight of model rockets weighing *between* 1 pound and 3.3 pounds provided the nearest FAA Air Traffic Control Facility was notified at least 24 hours in advance of the proposed flight; no waivers or permissions are required provided the operations are conducted in accordance with the very liberal regulations of FAR Part 101, Subpart A, paragraphs 101.1(a)(3)(ii)(a) through (d).

The United States Postal Service

On April 2, 1958, the U.S. Post Office Department first gave permission to ship model rocket motors through the mail. As the outstanding safety record of the hobby evolved — there has never been a transportation shipping accident or fire caused by model rocket motors or one in which they were involved — the U.S. Post Office Department re-issued its mailability permission on December 22, 1970 as shown in the appended letter. Model rocket motors continue to be shipped by the U.S. Postal Service under the same lack of restrictions.

The Consumer Product Safety Commission

Two important actions relating to model rocket motors were taken by the Commissioner of Food and Drugs under the Federal Hazardous Substances Act that is now under the jurisdiction of the Consumer Product Safety Commission.

The first was an exemption of model rocket motors from classification as a banned hazardous substance issued on August 29, 1969.

The second was an exemption dated February 13, 1970 exempting model rocket motors from the labelling requirements of the Federal Hazardous Substances Act and setting forth special requirements because of the small size of model rocket motors.

Copies of these documents as published in the *Federal Register* are appended.

PART SIX

ENDORSEMENTS

Over the years, an impressive number of organizations have endorsed model rocketry as a safe and education hobby and sport. This Part briefly presents a list of some of these. Additional information concerning the model rocketry programs of the various organizations may be obtained directly from them.

The United States Air Force

The United States Air Force was the first organization to publicly endorse model rocketry in an all-command letter dated July 3, 1961. A copy of this historic letter and its enclosure are reproduced as one of the appendices.

The Civil Air Patrol

In 1965, the Civil Air Patrol headquarters began studies of a model rocketry program for its cadets. The NAR appointed NAR member and veteran CAP aerospace education officer, Sergeant Larry Loos, to coordinate the development of this CAP model rocket program. In May 1969, the CAP published CAP Manual 50-20, "CAP Model Rocketry Training Program," based upon the NAR Model Rocket Safety Code and competition program. Information about the current CAP model rocketry program may be obtained from CAP National Headquarters, Maxwell Air Force Base AL 36112.

The Boy Scouts of America

Model rockets were demonstrated to the scouting movement by the NAR at the 1960 Boy Scout Jamboree in Colorado Springs, Colorado. A Space Exploration merit badge now exists with a requirement to build and fly a model rocket according to the NAR Model Rocket Safety Code.

The 4-H Aerospace Program

In 1970, the 4-H Clubs adopted a model rocketry program based on the NAR guidelines and codes. 4-H Aerospace Program's Model Rocketry manual 4-H- B-82 and Model Rocketry Leader's Guide 4H-BU-0259 may be obtained from the 4-H Aerospace Program, Minnesota Extension Service, University of Minnesota, St. Paul MN 55108.

The Young Astronauts

In April 1985, the Young Astronauts introduced their model rocketry Curriculum Activity Package. Further information may be obtained from The Young Astronauts Council, 1211 Connecticut Avenue NW, Washington DC 20036.

Other organizations

The Department of the Army, the Department of the Navy, and the National Aeronautic and Space Administration (NASA) have endorsed model rocketry and hosted both national and international competitions at their various facilities.

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MODEL ROCKET ENGINE TESTS

PURPOSE OF TESTS: To determine and compare the hazards of confined model rocket engines in a fire, to those on an open shelf.

LOCATION: City of Alhambra, cut and cover dump site.

DATE: January 24, 1972

ATTENDING: Brian Richtmeyer, San Bernardino, California Division of Forestry; Doug Malewicki, L. M. Cox Mfg. Co., Santa Ana; Joe S. Sacco, Deputy State Fire Marshal, Sacramento; K. Gilgove, L. M. Cox Mfg. Co., Santa Ana; Clarence Quillen, Santa Ana Fire Department; W. L. Anthony, Santa Ana Fire Department; Mike Patterson, San Francisco Fire Department and Chairman, Model Rocket Subcommittee CFCA-FPOS-N Section; Gaylord Evans, California Hobby Distributors, Alhambra; Dane M. Boles, Estes Industries, Penrose, Colorado; Joe B. Day, Los Angeles County Fire Department; Dave Sisson, Brea Fire Department; Bill Dittman, Fire Prevention Bureau, Monterey Park Fire Department; Tom Brown, Fire Marshal Downey Fire Department; Roy R. Ludt, Chief, Alhambra Fire Department; and eight other members of the Alhambra Fire Department.

Many tests are known to have been performed over the years using loose packages or individual model rocket engines in fires, but absolutely no information was available to this department and none could be obtained on storing these sources of propellant in a tightly confined container such as a Class II magazine.

Would there be a detonation or explosion or simply a free burn? Many opinions were voiced with qualifications and uncertainties. This then was the purpose of the experiment with testing open stock materials secondary.

Having two model rocket launching sites, several hobby shops selling the supplies and a wholesaler in the industrial area storing 750 pounds of the model rocket engines, it was believed necessary that this test be performed to enlighten those people concerned with the safety of others in storing and handling the materials, as well as up-grading related regulations for their control.

Estes Industries of Penrose, Colorado was contacted and they willingly offered to supply whatever was needed for the tests.

Fire Prevention members constructed two separate wooden shelf structures to simulate those found in commercial stores. Hardwood used was 1/2-inch stock and built to form a bookcase-like structure four feet high by three feet wide, one being one foot deep and the other two feet. Each had a top and a middle shelf with a one-inch gap between the middle shelf and the 1/4-inch plywood back to allow heat to quickly penetrate the area between the shelves. Items stored on the middle shelves consisted of five quarts of liquid glow fuel, one unopened case of two gallons of airplane fuel, one unopened case of twelve pints of aircraft fuel, four large paint spray cans and eight small spray cans.

On the upper shelves were placed nine full and one empty assorted aerosol spray cans and horizontally placed nine unpackaged assorted engines, nine packaged assorted engines and ninety-six assorted engines in thin cardboard shipping tubes (three to each tube). Engines varied from size A - D.

Model Rocket Engine Tests

Bookcases were separated by a four-foot distance and each had solvent-soaked wooden fuel placed beneath the middle shelves. Both Bookcases were ignited simultaneously.

Within a two minute period the aerosol spray cans, on the top shelf, commenced to rocket, some straight up (approximately one hundred feet) and others in a wide arc (approximately one hundred and thirty feet) accompanied by a loud explosion comparable to a shotgun report. After about three minutes of burning the cans of fuel burst their caps (only one noticeably ruptured) and spewed out balls of flame four to five feet in diameter with loud "whump"-like sounds.

At about the four-minute mark the rocket engines commenced to ignite and continued to rocket for ten minutes, even after the collapse of the shelves. Upon ignition the smaller engines, (A and B), not stored in the shipping tubes, generally traveled less than twenty to fifty feet and many much less than that. However, the larger engines (C and D) with a greater amount of power did radiate some distance farther. Many of those engines in the shipping tubes fired just as a rocket and one traveled a distance of three hundred and seventy-five feet. Apparently when the middle or rear engine fired, the added weight in the nose caused it to maintain a more stable trajectory and they traveled a greater distance.

Conclusions:

A - Aerosol cans are both an exploding as well as a rocketing hazard as has always been recognized. If a weakened seam or a simple "pressure relief disc" could be devised and built into each container then the excess pressure could not build up sufficiently to blow the bottom out, as usually occurs, to achieve a rocket status and become a threat to life as well as a fire hazard.

B - Model rocket engines should be kept to a minimum on open shelves, particularly those engines in shipping tubes which will ignite and travel greater distances than previously thought possible. Due to their light weight and short ignition duration, however, they are much less a hazard to life or property than the aerosol containers.

C - Gallon or less size containers merely added fuel to the fire as expected, and the amount should be limited when mixed with other storage.

The primary purpose of the test was then run and this consisted of igniting a small arms ammunition box, with interior dimensions of 16" x 12" x 8", completely filled with approximately one hundred model rocket engines. The engines were of all sizes and some were loose while others remained in their packages or shipping tubes. The box was constructed of 3/4-inch thick wooden top, bottom and two sides and the two ends were 1-1/4 inches thick. The ignition source consisted of a 24" x 15" broiler pan filled with three inches of solvent.

The box was secured six inches above the level of the solvent which continued to burn for twelve minutes. At about this time mild wisps of smoke and fire from burning engines were observed to periodically shoot out the bottom of the box which continued to disintegrate as the pyrotechnic display intensified.

Model Rocket Engine Tests

Thirty minutes after ignition the area was wet down by firemen and a great deal of engines were observed lying on the ground with their casing charred without ignition of the solid propellant inside.

At no time was there any evidence of an explosion or any chain reaction energy release. A constant wildly erratic flying engine was the only hazard to contend with during this entire test portion.

Video tape pictures were taken by the Santa Ana Fire Department and 8 mm movie and still pictures were taken by the Alhambra Fire Department.

Conclusions:

1. Storage of a large quantity of model rocket engines can be more safely stored in a Class II type explosives magazine than loosely stored on a shelf, as it takes a much greater period of time to burn through the magazine (almost five times as long) and ignite the engines than it does for engine ignition on an open shelf.

2. There is no hazard of the entire magazine detonating at once.

Reported submitted by: Donald J. Nold
Fire Marshal
Alhambra Fire Department

TRUESDAIL LABORATORIES, INC.

CHEMISTS - MICROBIOLOGISTS - ENGINEERS

4101 N. FIGUEROA STREET
LOS ANGELES 90065
AREA CODE 213 • 225-1564

September 9, 1977

Laboratory No. 773209

Estes Industries, Inc.
Penrose, Colorado 81240

Attention: Joseph Connaughton

Re: Model rocket motors

We have completed testing on a number of model rocket motors. We were provided with a carton of B6-4 single stage model rocket engines, which contain 6 grams of solid propellant. The purpose of this test program was to determine the self ignition temperature of these engines.

The self ignition temperature is that temperature to which the subjects must be heated to spontaneously burn. A fixture was therefore prepared that would heat the engines at an even rate. The rocket engines were placed inside a 3½ inch diameter aluminum cylinder. The core of the cylinder was drilled out to provide a slide fit chamber into which the engine was placed. The thick walls of the aluminum block insured an even heat distribution. The device was left open on top to provide escape for the gases of combustion. Three thermocouples were installed in the block, close to the rocket engine case, to monitor temperature at different locations.

The fixture was then placed inside an autogenous ignition temperature measuring device (made to the requirements of ASTM D-2155), a thick walled cylindrical oven with heating coils within the walls and floor. The top was covered with a layer of heavy asbestos cloth to contain the heat but not allow a build up of pressure. The test set-up is shown in Figure 1.

Testing was conducted on 31 samples. The temperature was continually raised at a rate of approximately 13°F/minute in each test until ignition. The temperature was monitored with a calibrated Minneapolis Honeywell strip chart recorder. All engines fired between 562 and 627°F. A typical engine after test is shown in Figure 2. The individual ignition temperatures for each test are tabulated in Table I.

The average ignition temperature value was 589°F and the standard deviation from this value was 16°. Utilizing the normal distribution curve to represent the range of ignition temperature values for all rocket motors; this means that 68.3% of all engines will have ignition temperatures between 573 and 605°. Correspondingly, 99.7% of all engines would have ignition temperatures greater than 541° and less than 637°F (3σ boundary).

CONCLUSION

Testing of a sample of B6-4 model rocket engines indicated that the average self ignition temperature, or the temperature at which the engine will ignite, was 589°F. Utilizing a normal distribution curve, 99.7% of all engines will have ignition temperatures within 48° of this value. Since the propellant is the same in other engine models, there is no doubt that these results would be similar. Since these temperatures are much above the temperatures encountered during shipping and even above the temperatures at which wood and paper ignite there is no reason to believe that these engines would pose a hazard during shipping from a temperature standpoint.

Respectfully submitted,

TRUESDAIL LABORATORIES, INC.

Richard A. Pitel
Registered Professional Engineer
California License No. SF 1762

RAP:jw

TABLE I

Self Ignition Temperatures for Each Test Sample
(Degrees Fahrenheit)

1.	590°F	17.	567
2.	562	18.	581
3.	566	19.	611
4.	571	20.	601
5.	591	21.	577
6.	592	22.	579
7.	587	23.	572
8.	565	24.	583
9.	598	25.	584
10.	593	26.	576
11.	584	27.	586
12.	599	28.	617
13.	587	29.	603
14.	579	30.	627
15.	579	31.	596
16.	611		

Figure 1

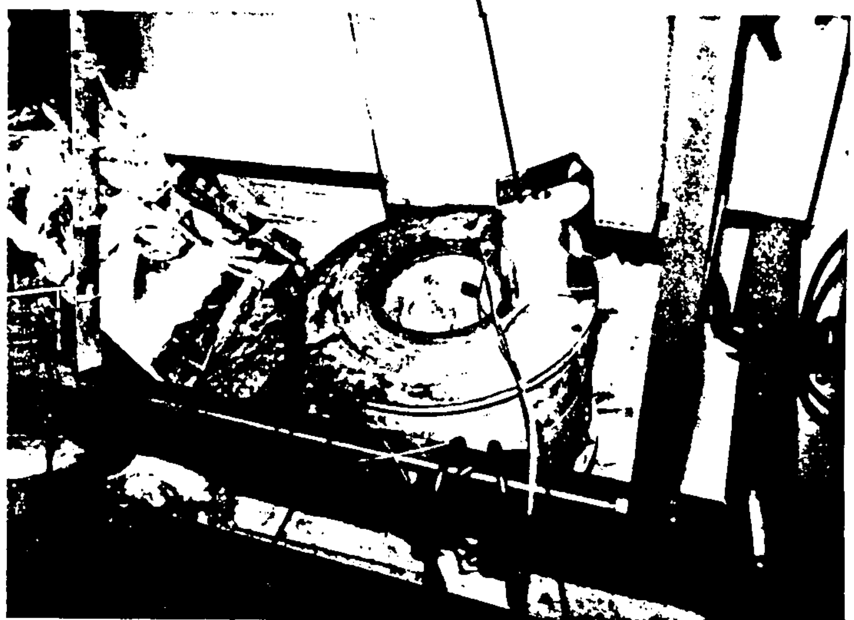

Figure 2

TRUESDAIL LABORATORIES, INC.

CHEMISTS - MICROBIOLOGISTS - ENGINEERS

4101 N. FIGUEROA STREET
LOS ANGELES 90065
AREA CODE 213 • 225-1564

September 28, 1977

Laboratory No. 773209-A

Estes Industries
Penrose, Colorado 81240

Attention: Joseph Connaughton

Re: Model rocket motors

An analysis has been performed to determine the mechanical energy required to reach the ignition temperature of a rocket motor. Tests were previously conducted to determine the self-ignition temperature of rocket motors and these tests were described in our report number 773209. The self-ignition temperature is that temperature to which the subject must be heated to spontaneously burn. These tests indicated that the ignition temperature of a rocket motor must be raised approximately 500^{o} above room temperature before it will ignite.

When a rocket motor is impacted, the energy of impact is absorbed by the motor in the form of heat. If the motor is impacted hard enough its temperature could be raised high enough to ignite. This analysis necessarily assumes that the rocket motor is originally undamaged and all the impact energy is absorbed over the whole mass of the motor.

The heat energy assumed by a material may be calculated by the following equation: $\Delta Q = cw\Delta T$, where ΔQ is the change in heat energy, ΔT is the change in temperature, w is the weight, and c is the specific heat which is defined as the heat capacity of any material divided per unit weight. It is defined such that the specific heat of water equals 1.0.

To determine the specific heat of a rocket motor, it was first coated with a thin layer of varathane to decrease water absorption and then placed into a beaker of water. The subject used was a B6-4 model rocket motor manufactured by Estes Industries. The water and motor were heated to approximately 180°F at which time the motor was quickly transferred to a beaker of cold water. The heat gained by the water was equivalent to the heat given off by the heated motor enabling a determination of specific heat. This value was determined to be .3 cal/gm/°C.

The required heat energy utilizing the above equation was calculated to be 1501 calories, or 4634 foot pounds. This represents the amount of mechanical energy required to ignite a rocket motor. This would be equivalent to a 463 pound weight, dropped from 10 feet such that the entire impact would occur on one rocket motor. Since there were 216 rocket motors in one case, any impact to the case would be absorbed by many other rocket motors so this energy would be much higher depending upon how the impact occurred (over a million foot pounds if the energy were absorbed uniformly over the entire carton).

CONCLUSION

A theoretical calculation of the energy required to ignite a rocket motor yielded a value of 4634 foot pounds for each rocket motor. This value indicates that such an impact is much higher than would be expected to occur during transportation even if the transporting vehicle were involved in a severe accident.

Respectfully submitted,

TRUESDAIL LABORATORIES, INC.

Richard A. Pitel
Registered Professional Engineer
California License No. SF 1762

RAP:jw

POST OFFICE DEPARTMENT

WASHINGTON, D.C. 20260

DATE: December 22, 1970

REPLY TO ATTN OF: KC/cdd

SUBJECT: Mailability - Toy Propellant Devices - your memo Oct. 26, 221:JAM:bv

TO:

Regional Director
U. S. Postal Service
P. O. Box 1979
Denver, Colorado 80201

Tests have shown that rocket engines subjected to fires do not create a hazard to postal personnel or equipment, or other mail, and the experience gained from past mailings has established that the engines can be mailed safely. Therefore, based on this evidence and information received from the Department of Transportation, packages not exceeding 25 pounds each, containing the engines will be acceptable subject to the provisions of Sections 124.1, 124.2 and 124.8, Postal Service Manual.

Full responsibility rests with the mailer for any violation of law (Title 18, United States Code; Section 1716) which might result from placing this matter in the mails.

Darwin E. Sharp
Director, Office of Mail Classification
Finance and Administration Department

SUBCHAPTER D - HAZARDOUS SUBSTANCES

PART 191 - HAZARDOUS SUBSTANCES: DEFINITIONS AND PROCEDURAL AND INTERPRETATIVE REGULATIONS

Toy Rocket Propellant Devices; Exemption From Classification as Banned Hazardous Substance

Fifteen comments, all in support, were received in response to the notice published in the FEDERAL REGISTER of July 10, 1969 (34 F.R. 11423), proposing that certain toy rocket propellant devices be exempted for reasons given from classification as "banned hazardous substances," as defined by section 2(q) (1) (A) of the Federal Hazardous Substances Act. The Commissioner of Food and Drugs concludes that the exemption is consistent with the purpose of the act and that the amendment should be adopted as proposed.

Therefore, pursuant to the provisions of the act (sec. 2(q) (1) (B) (i), 74 Stat. 374, 80 Stat. 1304; 15 U.S.C. 1261) and under authority delegated to the Commissioner (21 CFR 2.120), two new subparagraphs are added to § 191.65 (a) as follows:

§191.65 Exemptions from classification as banned hazardous substances.

(a) * * *

(8) Model rocket propellant devices designed for use in light-weight, recoverable, and reflyable model rockets, provided such devices:

(i) Are designed to be ignited by electrical means.

(ii) Contain no more than 62.5 grams (2.2 ounces) of propellant material and produce less than 80 newton-seconds (17.92 pound seconds) of total impulse with thrust duration not less than 0.050 second.

(iii) Are constructed such that all the chemical ingredients are preloaded into a cylindrical paper or similarly constructed nonmetallic tube that will not fragment into sharp, hard pieces.

(iv) Are designed so that they will not burst under normal conditions of use, are incapable of spontaneous ignition, and do not contain any type of explosive or pyrotechnic warhead other than a small parachute or recovery-system activation charge.

(9) Separate delay train and/or recovery system activation devices intended for use with premanufactured model rocket engines wherein all of the chemical ingredients are preloaded so the user does not handle any chemical ingredient and are so designed that the main casing or container does not rupture during operation.

A delayed effective date is unnecessary for this promulgation since this order establishes an exemption as contemplated by the Federal Hazardous Substances Act under certain conditions.

Effective date. This order shall be effective upon publication in the FEDERAL REGISTER.

(Sec. 2(q) (1) (B) (i), 74 Stat. 374, 80 Stat. 1304; 15 U.S.C. 1261)

Dated: August 29, 1969.

J.K. Kirk,
Associate Commissioner for Compliance.

[F.R. Doc. 69-10686; Filed, Sept. 8, 1969; 8:48 a.m.]

REPRINT FROM
FEDERAL REGISTER, VOL. 34, NO. 172 - TUESDAY, SEPTEMBER 9, 1969

PART 191 - HAZARDOUS SUBSTANCES: DEFINITIONS AND PROCEDURAL AND INTERPRETATIVE REGULATIONS

Toy Rocket Propellant Devices

The Commissioner of Food and Drugs has received requests from the National Association of Rocketry, Washington, D.C., and Estes Industries, Estes, Colo., submitted pursuant to section 3(c) of the Federal Hazardous Substances Act and §191.62 of the regulations thereunder to exempt toy rocket propellant devices from certain of the labeling requirements of section 2(p) (1) of the act.

Based on information submitted in the request, and other relevant material, the Commissioner concludes that the exemption can be granted under certain conditions. Because of the small size of the individual propellant devices, it is necessary to select the limited wording and information that would be of the most value to users. On this basis, the information set forth below must be used on the individual propellant devices, and full labeling must accompany any retail containers and appear on any accompanying literature that bears directions for use. Accordingly, pursuant to provisions of the act (sec. 3(c), 74 Stat. 374; 15 U.S.C. 1262) and under authority delegated to the Commissioner (21 CFR 2.120), §191.63(a) is amended by adding a new subparagraph, as follows:

§191.63 Exemption for small packages, minor hazards, and special circumstances.

(a) * * *

(36) Individual toy rocket propellant devices and separate delay train and/or recovery system activation devices intended for use with premanufactured model rocket engines are exempted from bearing the full labeling required by section 2(p) (1) of the act insofar as such requirements would otherwise be necessary because the articles are flammable or generate pressure: *Provided,* That:

(i) The devices are designed and constructed in accordance with the specifications in 191.65(a) (8) or (9).

(ii) Each individual device or retail package of devices bears the following:

(a) The statement "Warning - Flammable: Read instructions before use."

(b) The common or usual name of the article.

(c) A statement of the type of engine and use classification.

(d) Instructions for safe disposal.

(e) Name and place of business of manufacturer or distributor.

(iii) Each individual rocket engine or retail package of rocket engines distributed to users is accompanied by an instruction sheet bearing complete cautionary labeling and instructions for safe use and handing of the individual rocket engines.

Notice and public procedure and delayed effective date are unnecessary prerequisites to this promulgation, and I so find, since the Federal Hazardous Substances Act contemplates such modification of labeling requirements under certain conditions.

Effective date. This order shall be effective upon publication in the FEDERAL REGISTER.

(Sec. 3(c), 74 Stat. 374; 15 U.S.C. 1262)

Dated: February 13, 1970.

Sam D. Fine,
Acting Associate Commissioner for Compliance.

[F.R. Dec. 70-2287; Filed, Feb. 25, 1970; 8:45 a.m.]

REPRINT FROM
FEDERAL REGISTER, VOL. 35, NO. 39 - THURSDAY, FEBRUARY 26, 1970

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON 25, D.C.

REPLY TO
ATTN OF: AFPMP-12

SUBJECT: Model Rocketry

3 July 1961

TO: AAC (4), ADC (4), AFLC (4), ATC (4), AU (4), SAC (4), TAC (4), AFSC (4), MATS (4), ConAC (4), CAirC (4), PacAF (4), USAFA (4), USAFE (4), USAFSS (2), HQ COMD USAF (4), AFAFC (4)

1. This headquarters encourages the development of model rocket clubs and societies for hobbyists, in view of the expanding missile program and increased interest in rocketry.

2. The establishment of model rocket competition, as a part of the special services program, is also being considered at this time. It should be noted that unsupervised experimental or amateur rocketry is dangerous. Model rocketry, on the other hand, is essentially safe. Amateur rocketry, utilizing large metallic rockets powered by homemade fuels and rocket motors, requires extensive safety precautions, expert professional supervision, and large tracts of land for flight. Model rocketry is concerned with small, light, inexpensive rockets made of paper, balsa, plastic, and other non-metallic materials, powered by commercially available rocket motors. Anyone with hobby tools can build a model rocket, which is akin to model airplanes.

3. Creating interest in model rocketry, under official sanction, will tend to discourage amateur rocketry and help revent accidents. In turn, model rocketry will encourage and develop skills useful to the Armed Forces, such as aerodynamics, meteorology, electronics, optics, photography, and mathematics.

4. Further information is contained in the attachment to this letter.

FOR THE CHIEF OF STAFF

Russell G. Pankey

RUSSELL G. PANKEY, Colonel, USAF
Personnel Services Division
Directorate of Military Personnel

1 Atch
Guidelines for model rocket activity in the AF

GUIDELINES.FOR MODEL ROCKET ACTIVITY IN THE AIR FORCE

The following guidelines are provided and will be used in connection with any model rocket activity:

a. The National Association of Rocketry (NAR) is the Air Force approved organization for model rocketry.

b. NAR official standards and regulations will govern all model rocketry activity on Air Force bases.

c. The NAR Safety Code is mandatory for all Air Force personnel participating in model rocketry.

d. Homemade engines are prohibited.

e. Only those engines approved by The Standards and Testing Committee of the NAR will be used in model rocket activity.

f. Metal parts of any type will not be used in the fabrication of any part of a model rocket. A complete briefing, products list, bibliography, safety code, and NAR official standards and regulations may be obtained from NAR, Suite 1962, 11 West 42nd Avenue, New York 36, New York. There is no charge to major air commands who request this information.

g. The unit Personnel Services Officer having cognizance over model rocket activity will coordinate the selection of a suitable launch area and other launch activities with the appropriate base safety office.

U.S. Department of Transportation
Research and Special Programs Administration
400 Seventh Street, S.W.
Washington, D.C. 20590

The US Department of Transportation
Competent Authority for the United States

CLASSIFICATION OF EXPLOSIVES

Based upon a request by Dane Boles on behalf of Quest Aerospace, 519 West Lone Cactus Drive, Phoenix, Arizona, the following items are classed in accordance with Section 173.56, Title 49, Code of Federal Regulations (49 CFR).

U.N. PROPER SHIPPING NAME AND NUMBER:

Model Rocket Motor (Domestic), NA0323 (see note 1)

U.N. CLASSIFICATION CODE: 1.4S

REFERENCE NUMBER	PRODUCT DESIGNATION/PART NUMBER
EX-9605002	#A6-4, #B6-0, #B6-2, #B6-4, #B6-6, #C6-0, #C6-3, #C6-5, #C6-7

Note 1 - May also be shipped as UN0432, Articles, pyrotechnic, 1.4S

Approved by:

Alan I. Roberts
Associate Administrator
for Hazardous Materials Safety

JUN - 4 1996
(DATE)

MATERIAL SAFETY DATA SHEET
Quest Model Rocket Motors

QUEST AEROSPACE, A Division of TOY BIZ, Inc.
519 West Lone Cactus Drive, Phoenix, Arizona USA 85027-2921
Phone: (602) 582-3817 / Fax: (602) 582-3828

HAZARDOUS INGREDIENTS / IDENTITY INFORMATION

Hazardous Components: Contains pyrotechnic composition - a solid mixture of oxidizer and fuel that will burn if ignited. These items are classified as UN 1.4S explosives by the U.S. Department of Transportation. Proper shipping name and number is Model Rocket Motor, NA0323 or Articles Pyrotechnic, UN0432. No chemical composition is exposed during normal handling and storage.

PHYSICAL / CHEMICAL CHARACTERISTICS

Solubility in water: Soaking in water will render inert.

Appearance and Odor: All pyrotechnic composition is contained in a cardboard casing.

FIRE AND EXPLOSION HAZARD DATA

Extinguishing Media: Flood with water if a small number of motors are involved.

Special Fire Fighting Procedure: Do not use suffocation methods - devices contain their own oxygen. If a large number of motors are involved prevent the spread of fire and allow them to burn.

Unusual Fire and Explosion Hazards: Motors may fly about in the event of a fire.

REACTIVITY DATA

Stability: Stable   Conditions to Avoid: Open Flames Smoking.

Incompatibility (Materials to Avoid): Exposure to water will cause motors to deteriorate.

Hazardous Decomposition or Byproducts: Smoke, nitrogen oxides and sulfur oxides may be produced in a fire.

Hazardous Polymerization: Will not occur.

HEALTH HAZARD DATA

Health Hazards: Exposure to finished items does not pose any health hazard.

PRECAUTIONS FOR SAFE HANDLING AND USE

Steps To Be Taken In Case Material Is Released or Spilled: No smoking or open flames in vicinity of spilled material. Carefully pick up and place items in cardboard carton. Sweep up any exposed chemical composition with a natural fiber brush.

Waste Disposal Method: Dispose by soaking in water, or by burning in compliance with state and local regulations.

Precautions To Be Taken In Handling And Storage: Avoid open flames, smoking and high temperatures (above 120° F). Keep shipping cartons cool and dry.

CONTROL MEASURES

Respiratory Protection: None required when handling finished items.

Protective Gloves: None required.

Work / Hygienic Practices: No smoking in vicinity of motors or igniters.   File: MSDSSHT2

NAR MODEL ROCKET SAFETY CODE

1. Materials. My model rocket will be made of lightweight materials such as paper, wood, rubber, and plastic suitable for the power used and the performance of my model rocket. I will not use any metal for the nose cone, body, or fins of a model rocket.

2. Motors. I will use only commercially-made NAR certified model rocket motors in the manner recommended by the manufacturer. I will not alter the model rocket motor (engine), its parts, or its ingredients in any way.

3. Recovery. I will always use a recovery system in my model rocket that will return it safely to the ground so it may be flown again. I will use only flame-resistant bio-degradable recovery wadding if wadding is required by the design of my model rocket.

4. Weight and Power Limits. My model rocket will weigh no more than 1,500 grams (53 ounces) at liftoff and its rocket motor(s) will produce no more than 320 Newton-seconds (4.45 Newtons equals 1.0 pound) of total impulse. My model rocket will weigh less than the motor manufacturer's recommended maximum liftoff weight for the motors used, or I will use motors recommended by the manufacturer for my model rocket.

5. Stability. I will check the stability of my model rocket before its first flight, except when launching a model rocket of already proven stability.

6. Payloads. Except insects, my model rocket will never carry live animals or a payload that is intended to be flammable, explosive, or harmful.

7. Launch Site. I will launch my model rocket outdoors in a cleared area, free of tall trees, power lines, buildings, and dry brush and grass. My launch site will be at least as large as that recommended in the following table. (NOTE: For a circular area, the site dimension is the diameter in feet; for a rectangular area, it is the shortest side in feet.)

LAUNCH SITE DIMENSIONS

Installed Total Impulse (Newton-seconds)	Equivalent Motor Type	Minimum Site Dimensions (feet)
0 -- 1.25	¼A & ½A	50
1.26 -- 2.50	A	100
2.51 -- 5.00	B	200
5.01 -- 10.00	C	400
10.01 -- 20.00	D	500
20.01 -- 40.00	E	1000
40.01 -- 80.00	F	1000
80.01 -- 160.00	G	1000
160.01 -- 320.00	2Gs	1500

8. Launcher. I will launch my model rocket from a stable launch device that provides rigid guidance until the model rocket has reached a speed adequate to ensure a safe flight path. To prevent accidental eye injury, I will always place the launcher so the end of the rod is above eye level or I will cap the end of the rod when approaching it. I will cap or disassemble my launch rod when not in use and I will never store it in an upright position. My launcher will have a jet deflector device to prevent the motor exhaust from hitting the ground directly. I will always clear the area around my launch device of brown grass, dry weeds, or other easy-to-burn materials.

9. Ignition System. The system I use to launch my model rocket will be remotely controlled and electrically operated. It will contain a launching switch that will return to "Off" when released. The system will contain a removable safety interlock in series with the launch switch. All persons will remain at least 15 feet from the model rocket when I am igniting model rocket motors totalling 30 Newton-seconds or less of total impulse and at least 30 feet from the model rocket when I am igniting model rocket motors totalling more than 30 Newton-seconds of total impulse. I will use only electrical igniters recommended by the motor manufacturer that will ignite model rocket motor(s) within one second of actuation of the launching switch.

10. Launch Safety. I will ensure that people in the launch area are aware of the pending model rocket launch and can see the model rocket's liftoff before I begin my audible five-second count down. I will not launch a model rocket so its flight path will carry it against a target. If my model rocket suffers a misfire, I will not allow anyone approach it or the launcher until I have made certain that the safety interlock has been removed or that the battery has been disconnected from the ignition system. I will wait one minute after a misfire before allowing anyone to approach the launcher.

11. Flying Conditions. I will launch my model rocket only when the wind is no more than 20 miles per hour. I will not launch my model rocket so it flies into clouds, near aircraft in flight, or in a manner that is hazardous to people or property.

12. Pre-Launch Test. When conducting research activities with unproven model rocket designs or methods I will, when possible, determine the reliability of my model rocket by pre-launch tests. I will conduct the launching of an unproven design in complete isolation from persons not participating in the actual launching.

13. Launch Angle. My launch device will be pointed within 30 degrees of vertical. I will never use model rocket motors to propel any device horizontally.

14. Recovery Hazards. If a model rocket becomes entangled in a power line or other dangerous place, I will not attempt to retrieve it.

FOR MORE INFORMATION, WRITE OR CALL:

The National Association of Rocketry
1311 Edgewood Drive
Altoona WI 54720

1-800-262-4872

E-mail narhq@eau.net

or

visit NAR's Internet web site:

http//www.nar.org