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Early Experimental Programs of the American Rocket Society 1930–1941

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This paper discusses the evolution of the American Rocket Society and its experimental programs from the early liquid rocket launches, through static firings of engines, to the experimental aerodynamic development of rocket shapes. The American Rocket Society was founded in 1930 as the American Interplanetary Society by a small group of science-fiction writers who were intrigued by the concept of interplanetary travel or space flight. A short time after its forming, the interplanetary society had become a more down-to-Earth organization. Within a matter of months, a "program of research on the rocket and its possibilities" had been undertaken. Out of this initiative and a trip by one of the founding members to visit the German Interplanetary Society, the Verein fur Raumschiffahrt E. V. Geschaftsstelle Berlin in 1931, the experimental committee of the American Interplanetary Society was born. The experimental committee would develop five rockets, of which three would actually fly. Their most important contribution to rocketry at the time was the development of an experimental test stand, later used by one of America's first rocket manufacturing companies, Reaction Motors Inc. Four members of the American Rocket Society's experimental committee would be the founders of this company. The experimental phase of the American Interplanetary Society and later the American Rocket Society lasted only about 10 years but led to the advancement of rocket science. American Interplanetary Society's scope had moved far from its origins as group of space enthusiasts to amateur experimenters to the country's leading technical society for rocketry and jet propulsion.

Introduction: Early Years

THE American Interplanetary Society (AIS) was founded on 21 March 1930[1–4] by a group of 10 science-fiction writers who were interested in the concept of interplanetary travel or space flight. These 10 wrote or worked for Hugo Gernsback's magazine *Science Wonder Stories* and would form the core of the fledgling society. All but one would later leave as the society matured. Table 1 lists the founding members of the society. *Science Wonder Stories* was devoted to science fiction, with one of its main themes as interplanetary flight. The leader of this group and the first president of the society was David Lasser, the managing editor of Gernsback Publications *Science Wonder Stories.* Lasser had a B.S. and administration degree from the Massachusetts Institute of Technology, Cambridge, Massachusetts. The initial meeting took place in the third-floor apartment of G. Edward Pendray and his wife in New York City. The principal aims of this new society as stated in the four mimeographed pages of the first *Bulletin of the American Interplanetary Society* dated June 1930, were as follows:

> ... the promotion of interest in interplanetary exploration and travel, and the mutual enlightenment of its members concerning the problems involved. The society, despite its youth, has already begun to tackle seriously the peculiar problems in its field. Since the creation of public interest is of prime importance, the society has sought to awaken interest in itself as well as the ideas for which it stands. Meanwhile, it has also begun the scientific consideration of the technical side of its progam.[5]

In hindsight, the aims of the society were grandiose. The founders felt that with public support and interest a space program and interplanetary flight were easily obtainable. To some at the time, interplanetary flight was a common notion; as stated by the emanate French scientist Robert Esnault-Pelterie, author of *L'Astronautique*, a trip to the moon might be possible within 15 years, but first experiments costing perhaps $2,000,000 would have to be made.[6] Rocketry and space flight were talked about often in the literature of the age, but to the public of the 1930s the concept of rocket flight was an oddity and the proponents somewhat crazy. Society membership was listed initially at two grades: active members at $10 per year and associate members at $3 per year. This was somewhat expensive for the time.

The society initially set out to survey the entire field of information relating to interplanetary travel. "It is the purpose of the survey to bring together in a comprehensive collection all the writings on that and related subjects, and to outline the problem with all its attendant difficulties, together with proposals that have been made to solve them."[7] This survey was a daunting task and within a few months led to a program of research on the rocket and its possibilities, led by G. Edward Pendray.[8]

Gawain Edward or G. Edward Pendray was one of the original organizers and the first vice president of the American Interplanetary Society. At the time of the formation of the society, Pendray was a reporter for the *New York Herald Tribune* and part-time writer for *Wonder Stories.* He was born in Nebraska and grew up on a Wyoming ranch, received his education at the University of Wyoming and later Columbia University. Over the years while employed at the *New York Herald Tribune*, he was successively a reporter, assistant city editor, picture editor, and science editor. For three years he was science editor of the *Literary Digest.* He would hold the positions of vice president, president, secretary, and editor of *Astronautics* during his tenure with the American Rocket Society (ARS). He would also be involved in all of the experimental work of the society before World War II. Professionally, from 1935 to 1944 he was assistant to the president of Westinghouse Electric and Manufacturing Company in charge of public relations and education. After this until his retirement in 1967, he ran his own public relations. A prolific writer on the promotion of rocketry and space travel, he would write numerous papers and articles along with the book *The Coming Age of Rocket Power* (1945) and coedit with Esther C. Goddard *The Papers of Robert H. Goddard* (1970). After his retirement he would be keep active as the director of the Harry Frank Guggenheim Foundation.[9]

The society's first year was spent promoting the concept of interplanetary travel through its meetings and its *Bulletin.* The first large

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Table 1 Founding members of the AIS

Name	Society position	1[a]	2[b]
David Lasser	President	X	X
G. Edward Pendray	Vice President	X	X
Charles P. Mason	Secretary	X	X
Nathan Schacher	——	X	X
Laurence E. Manning	Treasurer	X	X
Dr. William Lemkin	——	X	X
Fletcher Pratt	Librarian	X	X
Charles W. Van Devander	Editor of the *Bulletin*	X	——
Warren Fitzgerald	——	X	X
Everett Long	——	X	——
Lee Gregory (Mrs. Pendray)	——	——	X
Adolph L Fierst	——	——	X
Roy A. Giles	——	——	X

[a] Attended first meeting 21 March 1930. [b] Attended second meeting 4 April 1930.

public meeting held at the American Museum of Natural History in New York City featuring French scientist Robert Esnault-Pelterie and the film *A Girl in the Moon* was attended by over 2000 people![10] G. Edward Pendray had to read the presentation of Robert Esnault-Pelterie who at the last minute could not make the meeting because of illness. The little society of about 20 at the time then grew to 100. David Lasser wrote in his President's Annual Report:

> The conversion of scientists and technical men however constitutes a more difficult and laborious process. We must literally make converts, if not members, of all the technical men that we meet; so that these men will be centers for the spreading of our propaganda among others. I come now to what is perhaps the practical end of our work that concerned with experimentation on the rocket. I respectfully suggest the creation of a Committee on Experiments whose job it will be to 1. Decide where inexpensive but purposeful experiments can be made. 2. To lay out a general program for a series of experiments with costs. 3. To cooperate with research workers who wish to do experiments of their own and who solicit the society's advice. 4. To advise the society on how it may experiment to advantage on its own. This committee can, I believe, be one of the most useful that the society has, and I suggest that it be composed of men who have a personal flair for such work, and a practical sense of how it can be done.[11]

This report gave birth to the Experimental Committee of the AIS.

The other factor behind the experimental committee, its choice of chairman and the initial rocket configuration it chose to build, was a trip to Europe of G. Edward Pendray and his wife. During the trip, they planned as the emissaries of the AIS to visit the top experimenters in rocketry on the continent. Esnault-Pelterie and others were on vacation at the time and unreachable. They were able to visit Berlin and the Verein fur Raumschiffahrt E. V. Geschaftsstelle Berlin (VfR). Willey Ley showed the Pendray's around their Raketenflugplatz or rocket flying field. Pendray states:

> The only problem was that his English wasn't very good at the time, and our German was nonexistent. It was not easy to carry on technical conversations that were fully understood by either side. However, Ley and his VfR associates gave us the most memorable experience of our trip, an actual proving-stand test of a small liquid-fuel rocket motor using gasoline and liquid oxygen. We were not aware at the time that Goddard's successful shots since 1926 had been accomplished with liquid fuels, and this experiment at the Raketenflugplatz was the first of its kind we had ever witnessed. It filled us with excitement, and upon our return we reported fully to the Society, on the evening of 1 May 1931, both the method and promise of the German experiments.[12]

Pendray's report published in the May 1931 AIS *Bulletin*[13] stating that the VfR was the first to fly a continuously firing liquid rocket engine led to a misunderstanding between the society and Robert Goddard, a member of the society who is unknown to have attended any of the meetings. Goddard was very secretive in his experimental work, the only hint of his work being the publicity brought about by his 17 July 1929 liquid rocket launch that was mistaken for an airplane crash. The society was aware of Goddard's work, which was reported in G. Edward Pendray's article entitled "Definition and History of the Rocket."[14] But the details were lacking and in part incorrect. Goddard would use this date, not stating the first liquid flight of 16 March 1926, in his report to the Smithsonian and in his letter to the society correcting their mistake as to the first liquid rocket flight, published in the June–July 1931 *Bulletin*.[15] At the time liquid rocketry was in its infancy with many inaccuracies reported because of the secretive nature of the participants on one hand and the sensationalism of others on the other. An announcement was made in the May *Bulletin* that the final papers for the incorporation of the American Interplanetary Society were under the membership corporation laws of the state of New York.

During this time, September 1931, David Lasser's book *Conquest of Space*[16] was published. This book was the first in the English language available and geared toward the general public, which openly discuss the prospect of spaceflight. This book was the culmination of David Lasser's letters to the editor appearing in the *New York Times* and *Wonder Stories* along with his articles in *Scientific American* and other publications.

After Pendray's report at the May meeting, H. F. Pierce proposed that the society delay no longer and begin its own experiments. The experimental committee was formed with G. Edward Penday as its chair. In short order the committee set about building a liquid fuel rocket for flight after a few initial tests. As mentioned in the August 1931 *Bulletin*:

> Plans for the beginning of rocket experimentation by the society are maturing. The only obstacle at the time of writing is the obtaining of a suitable experimental field close to New York. When that had been obtained, it is expected that experiments on rocket combustion chambers will be made, and a body of data on the power developed by various chamber and different fuels will be built up.[17]

The actual construction of the rocket was not of the most concern, but rather finding a suitable site.

AIS/ARS Rocket No. 1

Pendray and Pierce "using rule-of-thumb assisted by faith" set off to design rocket no. 1.[18] Considering they had never build a rocket before and Pendray had only seen and studied the VfR rockets, this was a bold endeavor. The initial rocket was patterned after the two-stick Repulsor type rocket of the VfR, which Pendray had seen during his visit to Germany and discussed with Willy Ley of the VfR. Figure 1[†] shows a schematic the VfR two-stick Repulsor, Mirak no. 3 from the May 1931 *Bulletin*. H. Franklin Pierce constructed the AIS rocket in a small shop set up in the basement of his apartment house in the Bronx, New York, and was completed in January of 1932. The society officially announced its building of rocket no. 1 in the December 1931 *Bulletin*:

> We are now actually building a small rocket—a preliminary experiment which we expect will lead soon to much more important ones. The first rocket will probably be completed in about a month; if all goes as planned. It will be a rocket of the two-stick Repulsor type, standing about six feet high, and will be equipped with an automatic parachute, though it will probably not develop sufficient lift to carry any instruments. We cannot, of course, predict at this stage how high it will go. This will depend upon the total weight when it is finished, and also upon the efficiency of our motor, which is patterned after that used by the German Experimenters, with certain slight variations. We will use as fuels liquid oxygen and high-test gasoline.[19]

The rocket consisted of two parallel cylindrical tanks of aluminum piping each 5.5 ft long and 2 in. in diameter. The tanks were held at the top by a framework that supported the motor and its cooling

[†] All figures are from the original journals of the American Rocket Society, originally called the American Interplanetary Society. Issue numbers and page numbers where the photo can be found follow the image caption along with original image credit.

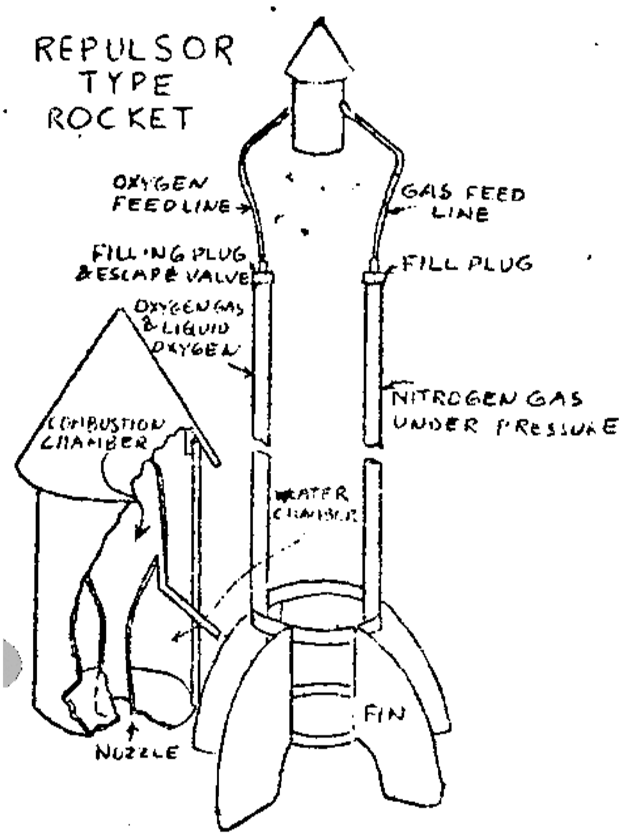


Fig. 1 Sketch of two-stick Repulsor rocket (No. 14, p. 3).

jacket, electric start valves, and a cone-shaped nosepiece containing the parachute. Four fixed-sheet metal aluminum vanes or fins were attached at the base of the rocket for guiding in vertical flight. The propellants for the rocket were pressure-fed liquid oxygen and gasoline. The pressure to feed the propellants was from two sources: the oxygen was from partial evaporation or boil off, whereas the gasoline was pressurized by an auxiliary tank of nitrogen. The parachute mechanism was kept closed by the pressure of the nitrogen and would release when this pressure was at the termination of firing. The motor was an aluminum casting, duraluminum, 3 in. in diameter and 6 in. long with walls of 0.5 in. The rough casting by the Aluminum Company of America was machined and drilled by Pierce for fuel inlets and other fittings in his basement. It was encased in a water jacket in the shape of a cocktail shaker. Loaded with fuel, the rocket weighed 15 lb, was to develop 60 lb of thrust, and have an acceleration of $3g$. The procurement and materials for this rocket were somewhat unorthodox by today's standards. The nose cone was constructed from a ten-cent-store saucepan. Mrs. Pendray made the parachute from a scaled-down pattern for a professional aviation parachute out of store silk pongree. The water jacket was constructed from a promotional cocktail shaker from a chocolate milk company given away as a premium. The cast aluminum motor was one of several donated free of charge by the Aluminum Company of America. George V. Slottman, an officer of the Air Reduction Company, furnished 15 L of liquid oxygen free of charge. They were to repeatedly be of service to the society. Later the society obtained an used liquid-oxygen handling container for $15; a new one would have been $100. The fuel for the rocket was poured into the tanks using a coffee pot from the handling container. The cost of the rocket was listed as $30.60 and an additional $18.80 for the test stand for a grand total of $49.40 (Ref. 20). The cost breakdown for AIS rocket no. 1 is shown in Tables 2–4.

Figure 2 shows a sketch of AIS rocket no. 1 from an article in the March 1932 *Bulletin* by Pendray. This rocket along with most of the early rockets had a nose-mounted engine with aft-mounted tanks as compared to an aft-mounted engine as we are accustomed to today.

Table 2 Cost breakdown of AIS rocket no. 1

Rocket component	Cost, $
Motor casings (3)	4.50
Tanks (standard tubing)	3.00
Fuel tubes, etc.	1.00
Valves, etc.	0.50
Sheet aluminum	1.50
Machine hire (for special work, etc.)	10.00
Parachute material	5.00
Parachute case	.10
Incidentals (est.)	5.00
Total	30.60

Table 3 Cost breakdown of test for AIS rocket no. 1

Testing component	Cost, $
Material for test rack (wood)	10.00
Nitrogen (express)	1.20
Gasoline	0.10
Batteries, wiring, etc., for remote control	2.50
Oxygen (contributed)	0.00
Incidentals	5.00
Total	18.80

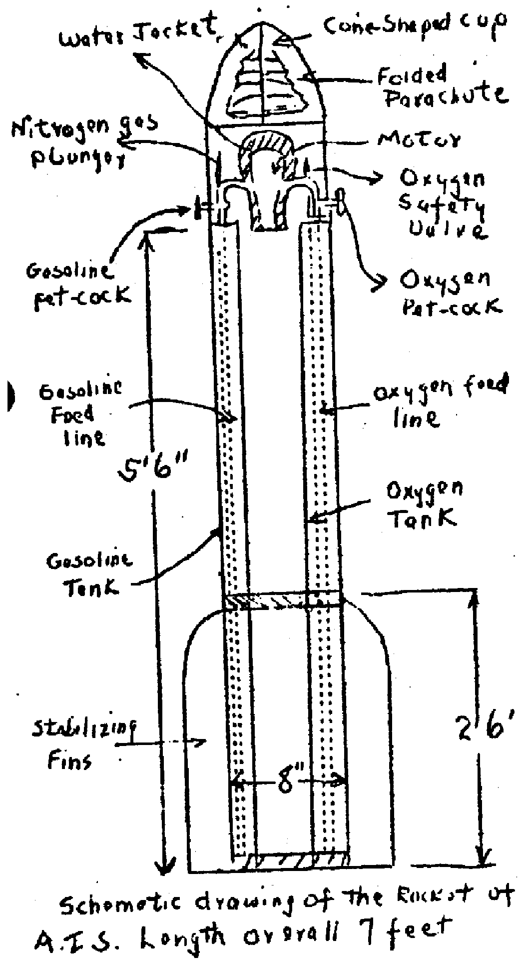


Fig. 2 Sketch of AIS rocket no. 1 (No. 17, p. 3).

The society published an article on the basic experimental techniques to determine the operating qualities of a rocket motor. Described in the article as "a series of simple, but fundamental rocket experiments,"[21] these tests accepted by the experimental committee for their own early rocket experiments were later used in the initial testing of rocket no. 1 (Figs. 3 and 4). The test presented was to determine the power, efficiency, and general value of various rocket combustion chambers.

Table 4 Total cost for AIS rocket no. 1

Item	Cost, $
Rocket	30.60
Test	18.80
Total	49.40

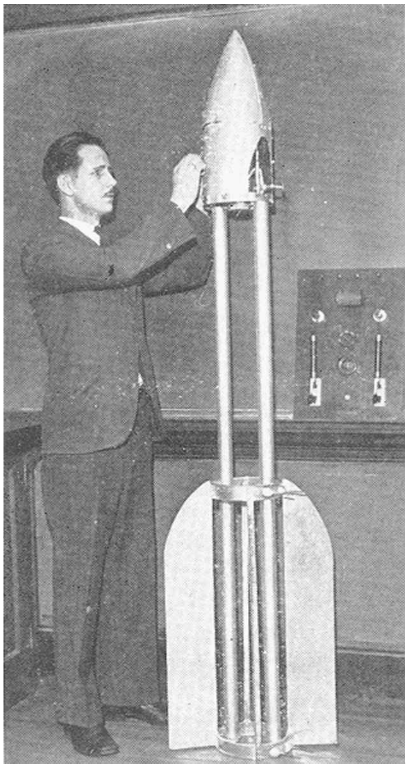


Fig. 3 Photograph of AIS rocket no. 1 (No. 39, p. 4), Acme.

A series of preliminary tests were performed on the rocket. The first test was to verify whether the tanks could handle the pressure required to operate the rocket. Nitrogen gas under 3000 lb of pressure was used for the test. The equipment for the test was donated and loaned to the society, sometimes under interesting methods for the tests. The Air Reduction Company gave several feet of pressure tubing and a pressure gauge and Schrader Tire Valve Company supplied special pressure valves. This test proved successful and showed that the tank would hold pressure to at least 1000 psi, although 300–400 psi was the required range. Next, the actual propellants would be used, oxygen and gasoline; for this a remote location would be required. The search would last all summer. In the August issue of *Astronautics*, it was announced that a flying field had been found, located on a farm near Stockton, New Jersey, with permission granted by the owner, Ace Hewitt. "A firing stand will be located on the field and several weeks will be devoted to testing the rocket before it is finally sent aloft. If the tests are successful the rocket will be shot about October 10."[22] Work began in late August on constructing a rocket field. The original members assisting with the project were Lasser, Schachrer, Lemkin, Manning, Pendray, and Mrs. Pendray, and three later members who would play a large part in future experiments, Pierce, Alfred Best, and Alfred Africano. Two bomb-proof dugouts and a proving stand were constructed. The proving stand consisted of two round 14-ft-tall pieces of wood to act as rails for the rocket during launch held about 12 ft apart by wooden planks. The lower part sunk in the ground and was protected by sandbags, stones, and earth from flame. The launcher guides were soaped to allow the guide rails on the rocket to slide. The rocket was held to the ground by a 12-ft pole allowed to pivot, attached to an upright post at one end and a coil spring at the other attached to the proving stand. This pivoting pole arrangement allowed the upward thrust of

Fig. 4 AIS rocket no. 1 test (No. 39, p. 4), Acme.

the rocket to be transferred to the pole then the spring, allowing for a captive full-up engine test. The first tests were of propellant loading first pressurized gasoline and then liquid oxygen (LOX). The gasoline loading went fine, but a design flaw emerged during the LOX loading. It was discovered that the 0.5-in.-diam fill hole was too small to adequately load LOX without the majority of it evaporating before the tank was filled. After experimentation, the quart tank could be loaded in about 15 min using 3 quarts of LOX. Once the LOX was loaded, the tank pressurization test occurred and was successful. During the following cold-flow test, the rocket's second weakness was discovered. The valves were opened by springs held closed by fuse wire operated by a knife switch in the dugout. The fuse wires were shown to be temperamental in operation occasionally requiring Piece to manually using a long stick to break the fuse wire, allowing the release of the LOX and gas in the first test.

The next set of tests was conducted on a cold and rainy 12 November 1932. By late afternoon all was ready for the engine fire test. The gasoline tank was filled with a pint and a quarter of standard filling-station gasoline, half ethyl and half clear gasoline. The ethyl was used to slow down the burning preventing chugging and backfire. The LOX tank was filled and the fuse wires connected. The rocket was to be lit by Lasser using a gasoline-soaked torch because the third problem of the design had become apparent during testing. The electric firing mechanism did not work, and so the torch was to be used. At about 1700 hrs, the pressure was allowed to build in the tanks that the fuse lit under the rocket and the switches operating the tank valves thrown.

Pendray described the test as follows:

> For an instant there was a great flare, as the pure oxygen struck the burning fuse. In an instant the gasoline was also pouring into the rocket. The fuse, the flare, and the uncertainty about the performance of our rocket motor all disappeared at once, as, with furious hissing roar, a bluish white sword of flame shot from the nozzle of the combustion chamber, and the rocket lunged upward against the retaining spring. . . . The flame was about twenty inches in length, clear and clean, of a bluish-white color, and quite steady. There was none of the chugging, choking or backfire we had expected. The sound was even and powerful throughout the test. At the last, just before the firing ceased, the noise changed a little. . .this change in sound indicated the liquid oxygen had been exhausted, and that the flame there after was supported for a second or so by the oxygen gas which flowed under pressure from the tank. Suddenly we knew the oxygen supply had been exhausted. There was an excess of gasoline as we had planned. This now came spurting out throwing a shower of fire all around the foot of the rocket and proving stand.[23]

During the test, the test personnel became so moved by the firing that they left the safety of the dugout and forgot to measure the burn time. After the test an immediate examination of the rocket revealed the water-cooling tank hot to the touch, the nozzle clean and bright, and soot in the throat likely left by the final shot of gasoline. Marks on the guide rails showed the rocket produced a constant 60 lb of lift. Based on fuel usage, the firing time was between 20 and 30 s. It was

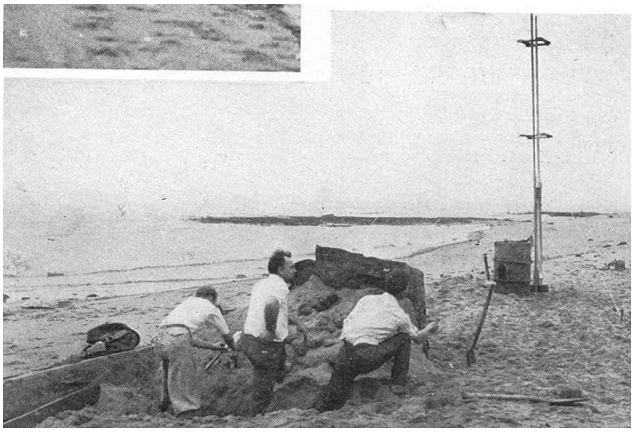


Fig. 5 Launch of AIS rocket no. 2 (No. 39, p. 5).

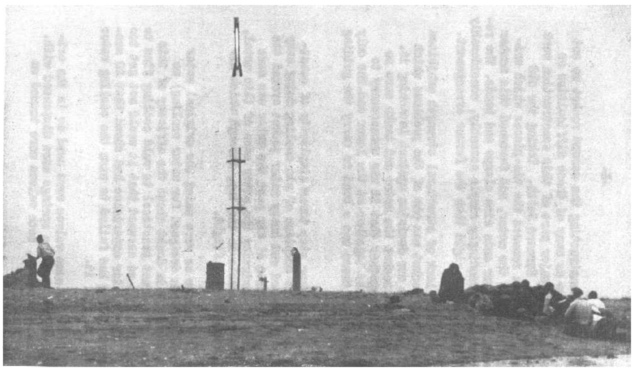


Fig. 6 Launch of AIS rocket no. 2 (No. 26, p. 4), Acme.

calculated that the 15-lb rocket in a vacuum would have ascended to a height of 16 miles. This was somewhat optimistic on their parts but did show that if the rocket were to have been in free flight, not a static test, it likely would have flown at least off the rails.

The next day the experimenter returned to make a flight. The weather would not cooperate, and they encountered a problem with the feedlines freezing, likely because of water in the lines. In preparing for a final test, the rocket was dropped while being placed in the proving stand. The rocket proved to be very fragile and was damaged beyond repair as the parachute apparatus and trusses were badly bent. The experimenters felt that had the weather cooperated they would have surely flown, and although the flight would not have been particularly important experimentally it would have been spectacular. A list of eight lessons learned from the testing of rocket no. 1 is as follows[24]: 1) oxygen tank designed for low boil off and easy to fill, 2) sturdy design and able to withstand shocks without breaking, 3) fuel valves operated by self-contained springs, 4) electric ignition of the rocket, 5) permanent wiring on the rocket eliminating temporary connection problems, 6) streamlined design, 7) parachute at the base not nose or alternative method of recovery, and 8) ground equipment should be sturdy.

The history of this first rocket, even though it did not fly, is important because it laid the foundation for the future work of the society. This initial foray into the experimental side of rocketry gave the society experience that would be used in the construction of the next rocket, rocket no. 2. The wreckage from rocket no. 1 was taken by a young member, Bernard Smith, and used as the basis for rocket no. 2.

ARS Rocket No. 2

Work on rocket no. 2 began within weeks of the end of tests on rocket no. 1. Bernard Smith first removed any unnecessary parts from rocket no. 1. He removed the superstructure containing the parachute, nose cone, waterjacket, and other items that showed to be of little or no value during the initial tests. The motor was clamped securely between the two tanks. The aluminum fins were replaced with lightweight balsa wood along with a streamlined nose cone or bonnet with an opening in the end for air cooling of the motor. A detailed description is given in Ref. 25. Bernard Smith would later say the following:

> The best description of ARS-2 was that it grew by accretion .... In the light of today's knowledge much of the design approach was erroneous. Putting the rocket nozzle ahead of the centre of gravity did nothing to improve stability, nor did placing the fuel orifice near the nozzle throat produce an aspirating effect. Fortunately, these mistakes were not catastrophic.[26]

After the rocket was constructed, it suffered damage from being knocked over in the basement workshop. Repairs were made and the rocket readied for test.

A test site for rocket no. 2 was found, and a temporary proving field was setup at Marine Park, Great Kills, Staten Island, New York. The launching of rocket no. 2 was not uneventful (Figs. 5 and 6). A wooden stick with a string pull was used to open the fuel cocks along with a gas-soaked cloth placed under the nozzle to ignite the fuel. When the string was pulled, it separated from the stick. Bernard Smith ran out to the rocket from behind the beam wall to reattach the string pull and reignite the gas-soaked rag. He pulled the string, and the rocket was launched. The safety procedures were not what they would be today. It was also pointed out to Bernard Smith after the flight that when helping load the liquid oxygen his clothes had become permeated by the LOX vapors, which could have caused him and not the rocket to go up. He explained his actions away by saying "that I dreaded doing any more work on that rocket and wanted to see it disappear off into space so I could work on the next one."[27] At 1120 hrs on Sunday 14 May 1933,[28] rocket no. 2 was launched and had reached an altitude of about 250 ft after firing for about 2 s when a stuck valve caused the oxygen tank to explode. The rocket dropped into the water of the Lower New York Bay where it was rescued by two youths in a rowboat. The wreckage of the rocket was recovered. Franklin Pierce was tasked with assessing the wreckage for a root cause of the oxygen-tank explosion. Upon examination he discovered the fuels were not mixing properly, instead flowing out the shortest path scorching the nozzle walls. The oxygen-tank pressure valve was locked shut, and "at the bottom of the oxygen fuel tank there is a fuel pickup. This was found to contain a great deal of sediment. This sediment obstructed the free flow of oxygen into the motor, thus tending further to increase the pressure," Pierce stated in his report on the 1932 experiments. Despite the accident, the society felt it a success. As Pendray would state, "It was the first liquid-fuel rocket any of us had ever seen get off the ground, and considering the state of the rocket art at the time, was a very considerable triumph."[29] This rocket shot caused a surge of interest in the society and new members. The focus of the society changed from the literary or theoretical prospect of rocket flight to the technical and experimental considerations of rocketry.

ARS Rockets No. 3, 4, and 5

Three new rockets were built following the success of rocket no. 2. These were rockets no. 3, 4, and 5. These three rockets were each built by a different group of individuals from the experimental committee. As the individuals varied, so did the concepts and designs for the individual rockets.[30] Rocket no. 3 was designed and built by Bernard Smith and G. Edward Pendray; rocket no. 4 by Carl Aherns, Laurence Manning. Alfred Best, and John Shesta; and rocket no. 5 by H. Franklin Pierce, Nathan Carver, and Nathan Schachner.

Rocket no. 4 was the next to be built and tested. It was 7 ft, 6 in. tall with an average diameter of 3 in. From the base the rocket consisted of the liquid-oxygen tank followed by the fuel tank with the motor attached to the top of the fuel tank. The motor had a single combustion chamber with four brass nozzles at its base pointed slightly outward away from the tanks. Atop the motor was the recovery system that consisted of a parachute. Initially the rocket was to use an autogyro consisting of fold-out fins collapsed at the nose caused by air resistance on ascent and pulled open-on descent for recovery. The motor initially was to have a water-cooling jacket that was later discarded for the first test but added to the final design. The rocket also had new quick opening valves that would allow with

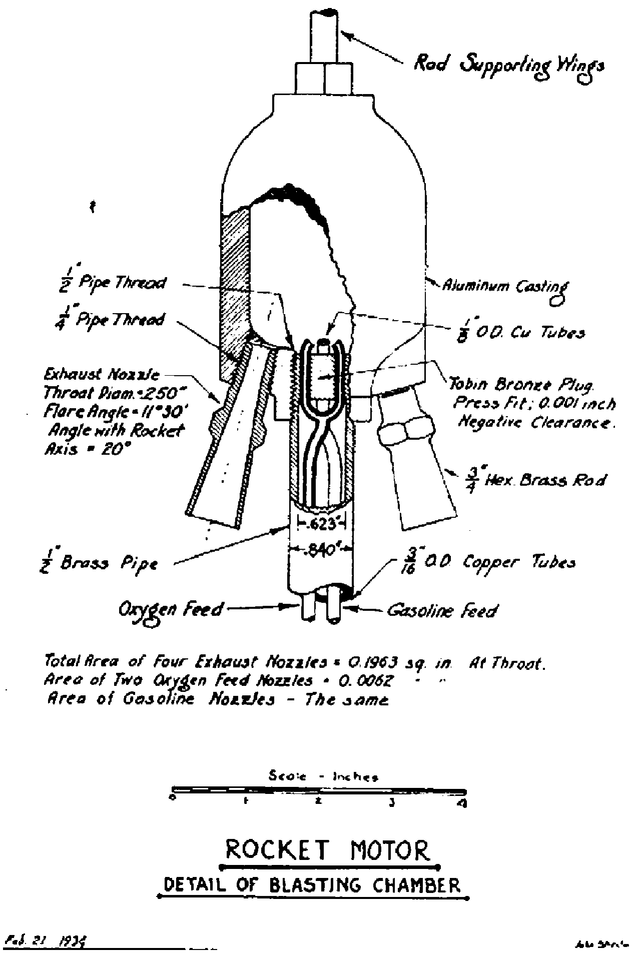
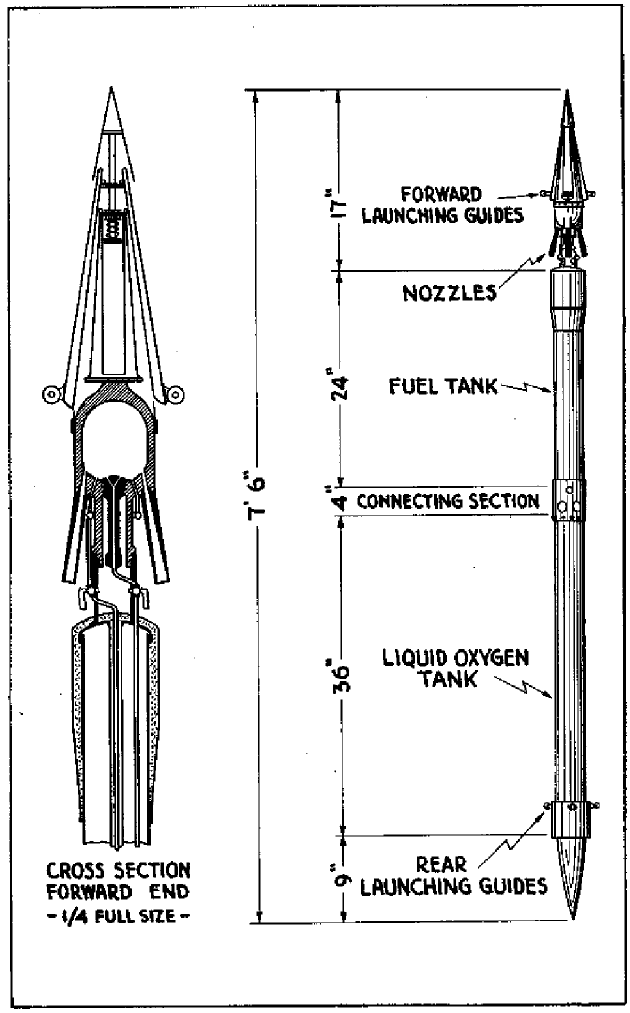


Fig. 7 Diagram of rocket no. 4 motor (No. 28, p. 5).



Detail of Rocket No. 4

Fig. 9 Diagram of rocket no. 4 (No. 27, p. 5).

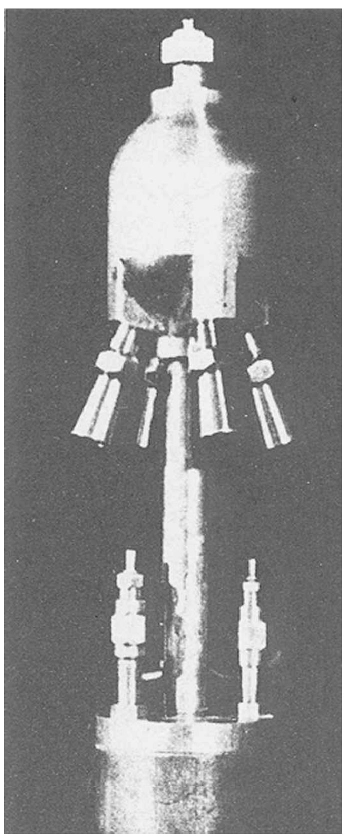


Fig. 8 Photograph of rocket no. 4 motor (No. 28, p. 5).

a single jerk of the cord full opening of the valve. Figures 7 and 8 depict the nozzle and motor of rocket no. 4, while Fig. 9 shows a diagram of the initial configuration of rocket no. 4. John Shesta was the man responsible for the major portion of construction of rocket no. 4 including the motor and nozzles.[31]

Rocket no. 4 was initially brought out to the proving field at Staten Island, New York, on Sunday, 10 June 1934, for its flight. Improvements had been made to the field since the last rocket flights. A steel launching rack had been constructed along with a new firing apparatus and instrumentation. The firing apparatus consisted of an electrically fired cartridge that could be started from the dugout timed to light the motor without heating the rocket. The rocket was fired and burned perfectly but failed to produce enough thrust to raise off the stand. This was believed to be caused by an insufficient flow of the fuel into the motor. The prolonged firing burned out the motor. The motor was replaced with an upgraded design with lager nozzles, fuel intake, and a water jacket for cooling (Fig. 10).

Flight of Rocket No. 4

"Experimental Rocket Number 4, a four-nozzle single motor rocket with tandem fuel tanks, was shot at 0831 hrs, on Sunday morning, 9 September 1934 [Fig. 11]. It was one of the most successful and spectacular shots ever obtained with a liquid fuel rocket."[32] This was the statement made to the society regarding rocket no. 4's flight. The time between the initial test and the flight was caused by the repair of the motor and the location of the proving stand by the bay, where there were numerous fishing boats in season. Rocket no. 4 proceeded to launch smoothly, but at an altitude of 350 ft the rocket started to weave, likely because of air resistance and a nozzle

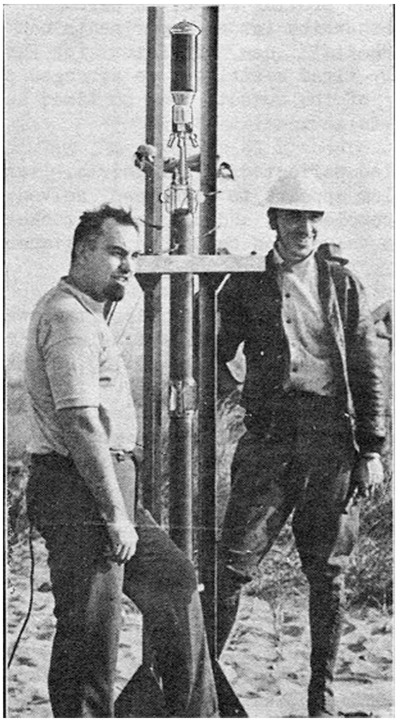


Fig. 10 Setup for test of rocket no. 4; Pendray and Shesta standing next to rocket (No. 29, p. 1).

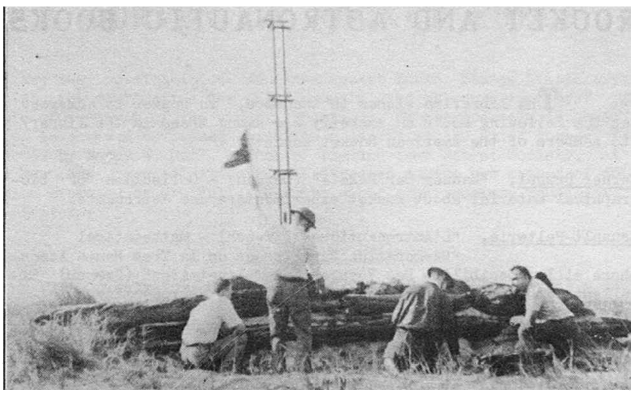


Fig. 11 Flight of rocket no. 4 (No. 29, p. 3).

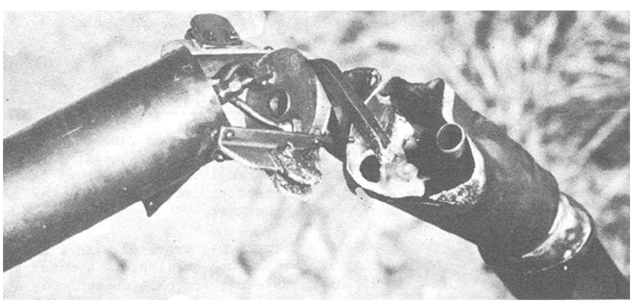
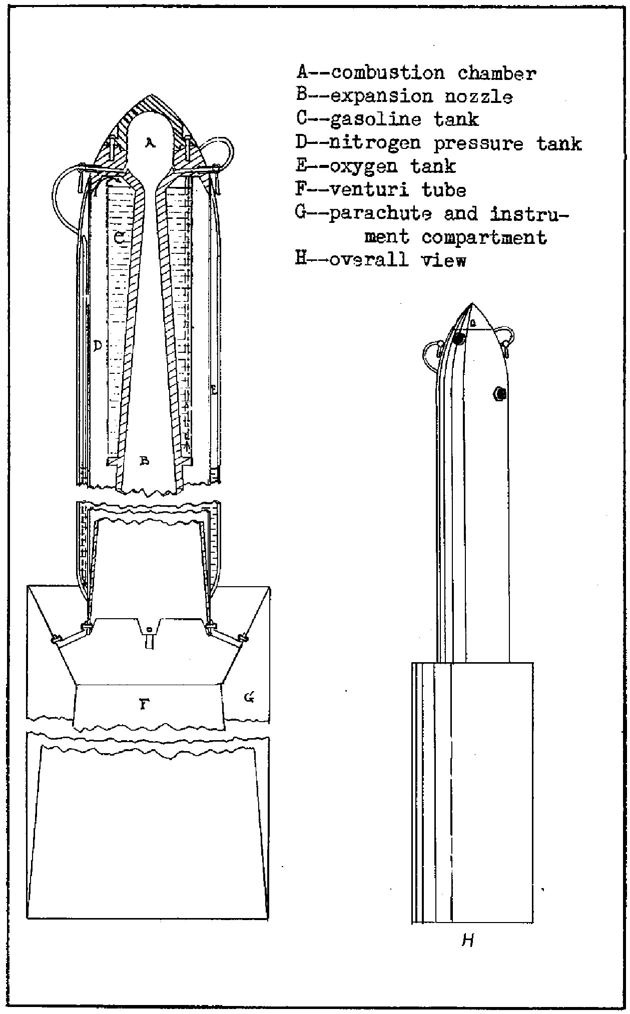


Fig. 12 Rocket no. 4 after the flight, nozzle section visible (No. 30, p. 4).

burn through. The rocket then proceeded to start descending while heading out to sea and had a forceful water impact because the rocket was still firing during this time. The rocket reached a maximum altitude of 382 ft and went down range 1585 ft. The maximum velocity of the rocket was calculated to have been more than 1000 ft/s or 700 mph, the highest velocity rocket at the time. The rocket was recovered and inspected. Figure 12 shows the recovered rocket. The inspection of the recovered parts showed everything mechanically worked fine except for the following four items:



Detail of Rocket No. 3

Fig. 13 Rocket no. 3 initial design (No. 27, p. 3).

1) The water jacket failed to cool the motor as a result of a layer of steam that formed on the nozzle stopping further transfer of heat to the water.

2) The firing head was faulty. The motor was cast as the previous single nozzle motor designs and then modified to accept the new multinozzle setup. This resulted in a weakening of the structural integrity of the motor that subsequently failed because of a burn through. This burn through caused the melting of the nozzle that blew out the bottom plate of the water jacket into the way of the nozzle exhaust resulting in the flight behavior of the rocket.

3) Erosion of the nozzle throats and chamber walls occurred where the combustion products impacted.

4) The parachute failed to open because it was designed to open in freefall that did not occur during the flight. Overall rocket no. 4 provided a number of lessons learned for future motors and flights.

Rocket no. 3 (Fig. 13) was arranged differently than previous designs. The fuel tanks were arranged concentrically, one around the other, encompassing the rocket motor. The tanks were constructed from duralumin tubes of increasing diameter, with a maximum diameter of 6.5 in. The order of the tanks was, from center to outermost, gasoline, nitrogen for pressurization, and then oxygen. The inner wall of one tank was the outer wall of the next. The motor was cast aluminum as with the previous rockets. It consisted of "an egg-shaped blast chamber (combustion chamber) leading into a conical expansion nozzle [Fig. 14]." The motor was mounted at the top of the rocket with the top of the combustion chamber protruding from the concentric tanks. The top of the combustion chamber and associated feedlines were covered with a removable cap, or fairing, which allow for easy access to the motor. The tanks were connected to the motor through feedlines constructed from copper

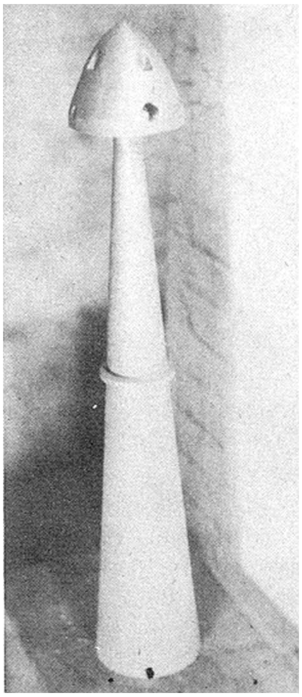


Fig. 14 Motor and nozzle assembly for rocket no. 3 (No. 28, p. 3).

tubing intersected with quick-release valves. The propellants were fed into the combustion chamber by high-pressure nitrogen and the LOX by the oxygen vapor pressure caused by boil off.

The design had four initial guiding considerations: 1) to keep the oxygen tank away from the rocket flame; 2) to test the possibility of cooling the motor with one of the fuels, the gasoline tanks were surrounding the motor; 3) to have the blast chamber and nozzle throat available after each firing for inspection; and 4) to see how much nozzle length effected the stability and thrust of the motor. The initial rocket design as shown in Fig. 13 varied from the as built by its lack of a venturi caused by weight considerations. A simple circular fin was used for stability. The completed rocket was 4 ft tall with a maximum diameter of 8 in. The recovery system was to be the same one used on rocket no. 4. Many of the parts of this system were damaged beyond repair from the landing of rocket no. 4.

The Test

The rocket was to be fired on Sunday, 9 September 1934, but after the flight of rocket no. 4, earlier in the day, there was not enough oxygen left for a launch, and so a ground test was performed. In the end this fact would not have mattered because of a design flaw.

The rocket was mounted in the launch rack (Fig. 15). The fuel tank was filled with 1.5 quarts of gasoline and the nitrogen tank pressurized to 300 psi. Initially two quarts of liquid oxygen were poured into the oxygen tank. Only a very small amount entered the tank bacause of boil off when the LOX encountered the warm tank and was also complicated by a small fill hole that required the use of a funnel. Both of these factors led to the outrushing gaseous oxygen, impeding the flow of the LOX adding problems and dangers to the fill process. A second two quarts of LOX were poured into the tank and the tank capped. Upon observation of the frost line, it was estimated that about half actually made it into the tank. The experimenters proceeded to wait for the safety valve to switch. After a minute and a half nothing occurred while the frost line decreased on the tank. At $2\frac{1}{2}$ min, the command to light the engine was given, and Bernard Smith threw the valves. A succession of "chugs" was heard from the rocket as if the oxygen and gasoline were feeding intermittently. This sound stopped, and a gasoline flame was visible from the nozzle. Based on the character of the burning, it was determined that the flame was just gasoline burning in the air. The flame was extinguished with sand. Upon examination of the rocket, no fuels were found in the tanks or the motor scored. Based on these facts and the chugging sound, it was determined that insufficient oxygen was in the tank to combust. The conclusion was that this design would require a greater amount of LOX to cool the tank than previous designs. A second test was performed with the same results, even though additional oxygen was filled into the tank than the previous test. The tank fill port was one of the major flaws of this design.

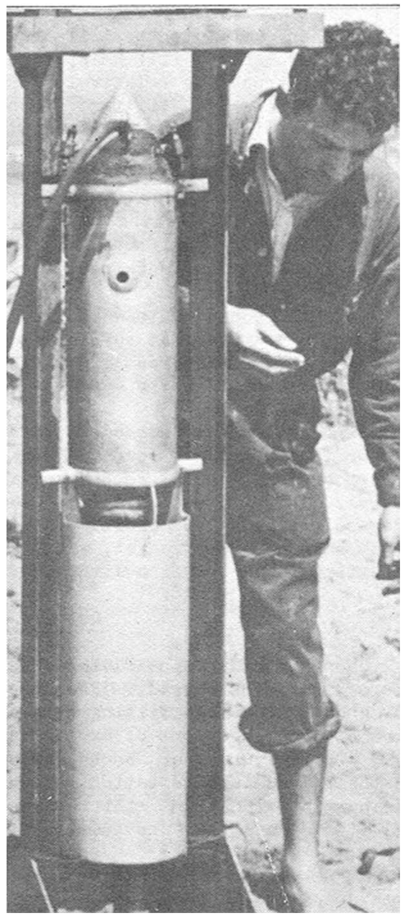
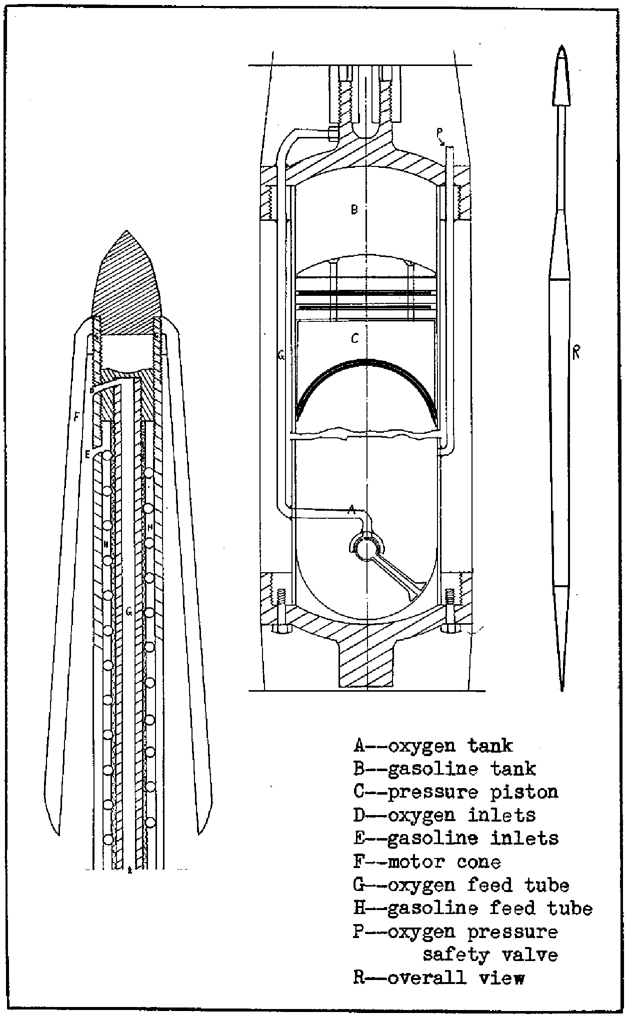


Fig. 15 Bernard Smith with rocket no. 3 in the launch rack (No. 30, p. 5).

9 September 1934 marked a turning point in the aims and methods of the society, specifically the experimental committee. In a sense the committee grew up. They went from a group of amateurs firing rockets that might or might not work into a technical organization using a systematic approach in the design of future rockets and motors. The committee started a systematic approach to the development and testing of rocket motors through the construction of a motor test stand or proving stand that would allow the recording of the capabilities of the motors. The society would not fly another liquid rocket, even though rocket no. 3 could have been modified. The rationale behind this is not known even with their new approach at rocket design. The society would test numerous rocket motor designs over the next seven years.

Rocket no. 5 was being built in parallel to rockets no. 3 and 4. This rocket was to be of such a unique design (as seen in Fig. 16) that proving stand tests of the components were proposed. The two unique features of this design were the fact that a cone where the fuel and oxygen were to be ejected was to act as both the combustion chamber and the nozzle and the second was that the tanks were not to be separate but a single tank with a piston or plunger separating the propellants. It was perceived this would eliminate the requirement for nitrogen to pressurize the fuel tank. No mentions are made of any proving stand tests of this concepts tank system or engine design.

During this time of great experimentation, the name of the society was changed. A vote was put forth to the membership to change the name of the society at the annual meeting from the American Interplanetary Society to the American Rocket Society. In the call



Detail of Rocket No. 5

Fig. 16 Diagram of rocket no. 5 (No. 27, p. 7).

for the annual meeting, the rationale for this change was noted, "In the opinion of many members adoption of a more conservative name, while in no way implying that we have abandoned the interplanetary idea, would attract able members repelled by the present name."[33] So on 6 April 1934, a vote was taken by the membership, and the name officially changed to the ARS.

Rocket Motor Tests

The end of 1934 brought about a time of rebuilding and a shift of energies. The experimental committee focused on the development of a proving stand capable of testing new rocket motors. The new apparatus would eliminate guesswork. The society was advancing "we could learn much more about rockets—not by building and flying them—but by building rocket motors and putting them through exhaustive ground tests."[34] The proving stand would allow the careful observation of the motors revealing design flaws, failures, and future improvements. This was a stark comparison to a rocket flight where the results were difficult to interpret from the wreckage. Proving stand no. 1 was designed and constructed by John Shesta. Measurements of thrust, fuel pressures, and blast, combustion, chamber pressure were taken via high-speed photographic film. The first series of tests took place on 21 April 1935 at Crestwood, New Jersey.

The test or proving stand was design for ease of usage and portability. The motor was mounted in order to fire upward, reducing the stand framework required. The entire assembly of motor and tanks was set on a hydraulic plunger attached to a pressure gauge to measure thrust. All of the gauges along with a timing dial were attached to a rack, sawhorse on right of photo for ease of recording by photography. Figure 17 is a photograph of a test firing on the proving stand. Figure 18 is a photograph of the proving stand showing the instrumentation setup. The motor has just burned through (note the flame outside of motor).[35] Figure 19 is a close-up of the motor setup. The oxygen feedline can be seen on the left along with the safety valve. Both the oxygen and fuel lines pass through a combined a check and quick opening valve. The chamber pressure tube can be seen on the right. The stand was designed to accept numerous motors designed by the committee and the society membership.

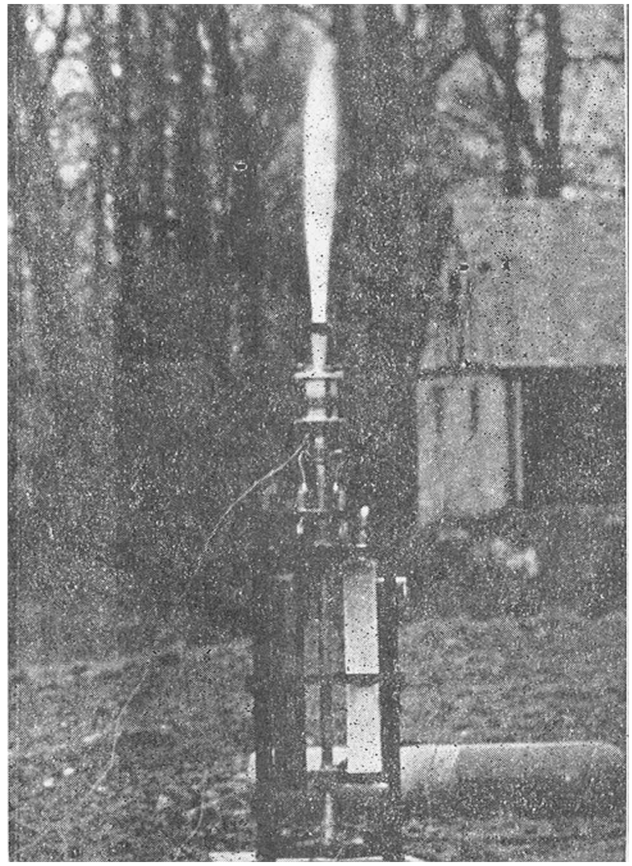


Fig. 17 Rocket motor firing, 21 April 1935 (No. 31, p. 1).

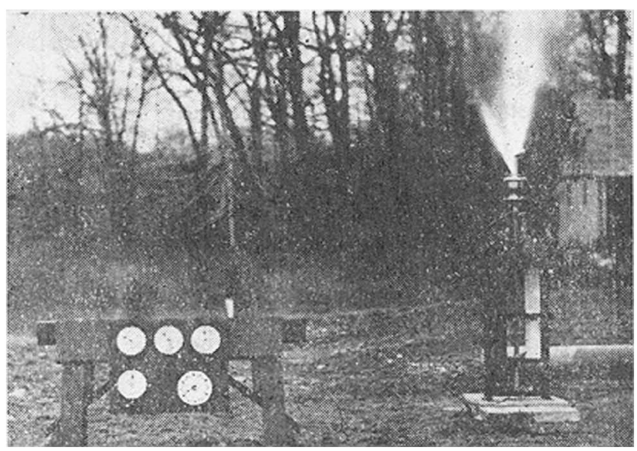


Fig. 18 Motor in proving stand no. 1 (No. 31, p. 6).

A series of five tests were run on two nozzle configurations at two pressure levels. The rocket motor used for the test was the same design as that of ARS rocket no. 3. The motor was constructed to be easily disassembled and interchangeable. The firing chamber was elongated 2 in. by the addition of an aluminum cylinder. The parts of the motor were fitted together with gaskets to prevent leakage and fastened by external flanges. The two nozzles tested were a 4-in.-long nozzle with a 0.5-in. throat and an expansion ratio of 5 to 1, and the second or long nozzle was 12 in. long with a 0.5-in. throat

Table 5 Results of first proving stand tests

Run	2	3	4	5
Nozzle	Short	Long	Short	Long
Pressure, psi	300	300	150	150
Duration, s	9	10	15	17
Max thrust, lb	59	46	25	17
Impulse, lb/s	430	380	280	180

Table 6 Results of second proving stand test

Run	1	2	3	4	6
Initial fuel press, psi	300	300	300	450	300
Diameter LOX inlet, in.	1/8	1/8	3/16	3/16	3/16
Diameter fuel inlet, in.	1/16	1/16	1/8	1/8	1/8
Diameter nozzle throat, in.	1/2	3/8	1/2	1/2	——
Max jet reaction, lb	57	54	90	128	90
Average jet reaction, lb	42	35	48	57	57
Duration combustion, s	8.5	13	8	6	8.5
Impulse, lb/s	357	455	384	342	485
Jet flow, lb/s	0.39	0.28	0.46	0.62	0.46
Jet velocity, ft/s	3450	4000	3340	2940	3970
Fuel input, ft lb/s in K	1155	1185	1920	2570	1520
Thermal efficiency	0.073	0.063	0.042	0.033	0.075

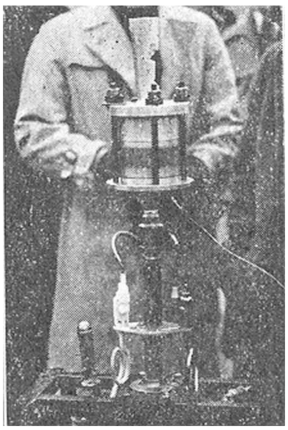


Fig. 19 ARS proving stand no. 1, 1935 (No. 31, p. 6).

and an expansion ratio of 25 to 1. Each nozzle was tested at two pressures, 150 and 300 psi. The stand held one pint of gasoline and two pints of oxygen. On the initial run the oxygen feedline blew out upon startup and was repaired. Table 5 shows the result of the last four tests.[36] The results of the tests showed that long nozzles were not effective, whereas higher pressures were. Each of the nozzles encountered scorching and burn through, leading to the conclusion that aluminum motors should not be used. Run time was also a concern. The lessons from these tests would be used on the next series.

The second series of motor tests took place on 2 June 1935 at the Crestwood Proving Grounds as they were called. This second series of tests were to determine the following; 1) effect on performance on varying throat area and initial pressure; 2) heat resisting value of nozzle material, nichrome vs aluminum; 3) effect of injecting fuels toward back of combustion chamber instead of toward nozzle; 4) heat resisting value of a carbon motor; and 5) alcohol vs gasoline as a rocket fuel.

The test motor consisted of a combustion chamber constructed of an aluminum cylinder 3 in. long and 2 in. in diameter capped with two hemispheres of 1-in. radius. The fuel inlets and connections were attached to one cap and the nichrome nozzle to the other. The nozzle total length was 4 in., a 1-in. converging section mating into a 12-deg cone 3 in. long with an exit diameter of $1\frac{1}{16}$ in.

The results from the tests were as follows and are shown in Table 6. 450 psi pressure provided only a small impulse, whereas the $\frac{3}{8}$-in. throat gave the longest combustion time and second highest impulse. The nichrome nozzle proved to work very well. The nozzle used for run 1 was also used in runs 3, 4, and 6. The aluminum nozzle used in the previous tests burned out after each run. The injection of fuel towards the combustion chamber was tested in run 1 and made little difference from standard practice. The carbon motor was tested in run 5 and burst at startup, and so no data are presented. Run 6 using alcohol produced the best performance and require further testing.

Table 7 Third series of motor tests results

Run	1b	2	3	4
Length of combustion chamber, in.	7	5	3	3
Ratio length to diameter	3.5	2.5	1.5	1.5
Maximum jet reaction, lb	57	73	56	64
Average jet reaction, lb	42	47.5	45	36
Duration of reaction, s	16	15	14.5	14
Impulse, lb/s	670	712	652	500
Average jet flow, lb/s	0.33	0.35	0.36	0.37
Average velocity, ft/s	4100	4350	4000	3100
Average fuel input, ft lb/s K	1030	1100	1130	1180
Average thermal efficiency	0.085	0.094	0.079	0.047

The third series of rocket motor tests were run on 25 August 1935. During these tests, a new fuel was used, which had shown promise in the last series of tests. Alcohol was used instead of the standard gasoline. The objectives of this series of tests were as follows: 1) the effect of using alcohol diluted with water as fuel, 2) correct ratio of combustion chamber length to diameter, and 3) performance of a special water jacket constructed of spun aluminum.

Testing was performed in the same fashion as previous tests. 300 psi was used as the initial pressure for all runs except 5, which used 450 psi. The feedlines consisted of $\frac{1}{8}$-in.-i.d. tubing for the alcohol feedline and $\frac{3}{16}$-in.-i.d. tubing for the gasoline feedline. A nichrome nozzle was used with a throat diameter of $\frac{1}{2}$ in. with an exit diameter of $1\frac{1}{16}$ in. The motors used in runs 1, 2, 3, and 5 were designed by John Shesta, and the spun aluminum water jacketed motor of run 4 was designed by Willy Ley. The results from the tests are shown in Table 7. Run 1 used a mixture of alcohol diluted 50% with water, which did not ignite so no data were obtained. A ratio of 2.5 produced the best thermal efficiency or the three runs made. The open water jacket failed to prevent the nozzle from melting.

The day ended with the last test a failure as already mentioned. The aluminum motor casing had a burn through as result of the failure of the water jacket to adequately cool the motor, causing an unexpected side load on the test stand overturning the motor and the stand. The motor then exploded. The society had learned that through testing defects in the design could be corrected before flight.

The society received notoriety from the press as a result of these tests. The *New York Times* for 26 August 1935 reported these tests as follows: "Motor for rocket explodes in test, Experiments at Yonkers end when stratosphere device is blown to pieces, Alcohol is used as fuel, Scientists gratified by data gained-noise alarms countryside for miles."

End of Official ARS Experimentation

The fourth set of static fire or field tests was held on 20 October 1935 at Crestwood, New York, and brought about an official end of ARS experimentation not by lack of enthusiasm or of technical difficulties but by an accident after the tests. The testing followed the same procedures as the previous tests. The nichrome nozzle was again tested, but this time burned through. As told in the board-of-director minutes for 24 October 1935:

> This accident had occurred after the official tests had been completed; thereafter, a group tried an experiment with some oxygen, as a result of which there was an explosion, which caused an injury to Miss Ramona Jennings, who at the time was standing some 300 feet from the scene of the experiment. She was among the spectators furthest removed from the explosion and was the only person injured.

The society moved to appropriate $150.00 toward the medical care of Miss Jennings, while disclaiming all responsibilities for the accident, on the condition she sign a release. Mr. Schachner, an

Table 8 Results of the 12 September 1937 model flight tests

Model	1	2	3	4	5	6	7
After prototype design of	Pierce	2-Step	Africano	Goodman	Wyld	Shesta	Repulsor
Distance from nose of rocket to							
Center of propulsion, in.	15	28	8	14	39	59	14
Center of gravity, in.	19	28	15	39	33	43	24
Center of area, in.	22	28	19	59	25	35	22
Bottom of rocket, in.	44	68	33	94	49	68	48
Weight of rocket at start, lb.	1.19	2.27	1.19	2.16	1.85	1.72	2.28
Estimated maximum altitude of flight, ft	1500	600	1500	400	200	300	100
Time of ascent, s	7	5	5	4	4	4	3
Time of descent, s	3	4	3	4	4	3	2

attorney, wrote up the release for the society and handled the details. For this he was made a member of the society. It was moved at this same meeting that Miss Jennings be made a life member of the society without payment. At the next two board meetings this incident was referred to and resulted in the end of official society experiments. The following two motions that were passed officially ended the experiments of the society [from 20 February 1935]: "The society adopt a new policy with respect to experimentation, namely, that the Experimental Committee will advise on rockets, and lend equipment, but the society will not partake in experiments"; and [from 9 April 1935] "In future the Society would not conduct any Experiments or tests, but would lend its support to any such endeavors as the Experimental Committee approved." This was not the first explosion at an ARS test. A rocket motor exploded on the test stand during an August 25 motor test as mentioned earlier, which brought notoriety to the society.

Officially the society would not conduct experiments, but the experimental committee continued to experiment by lending support and resources to the experimental committee members for their experiments. These acts were more of a legal technicality than an actual event. As seen later, society members continued to experiment until the beginning of World War II. These events did have an effect on the society in its expansion. At the time the concept of branches was rejected because of possible liability and "crack-pot" ideas some branches may have that would effect the status of the parent society.

Although these happening are mentioned in the board minutes, they never reached the society publication *Astronautics.* They did make it into the local papers. The 23 October 1935 *New York Times* reported "Woman Injured in Rocket Blast, Stratosphere Experimenters Secret Fuel Explodes at Tests in Yonkers Lot, Proving ground given up, Society decides as result of accident to go out into country for trials."

The problems with this series of tests resulted in a new test stand being designed to more adequately measure the flow of the propellants to the motor. It was felt that the incorrect mixture was used causing the burn through of the motor. Another important point concerning this set of tests was the list of spectators. Included in the crowd were some of the leaders in the scientific field such as George V. Slottman of the Air Reduction Sales Company, Major Lester D. Gardner, Secretary of the Institute of Aeronautical Sciences, and Alexander Klemin, head of the Guggenheim School of Aeronautics of New York University.

In 1936 the society was notified that Alfred Africano and the ARS had won the coveted REP-Hirsch Astronautics Prize for the year 1935. This was the first time an American had won the top prize in the new science of astronautics. The prize was awarded for the society report on the 1932–1934 rocket flights and ground tests along with Africano's paper "Design of a Stratospheric Rocket," which was based on the ARS proving stand tests.

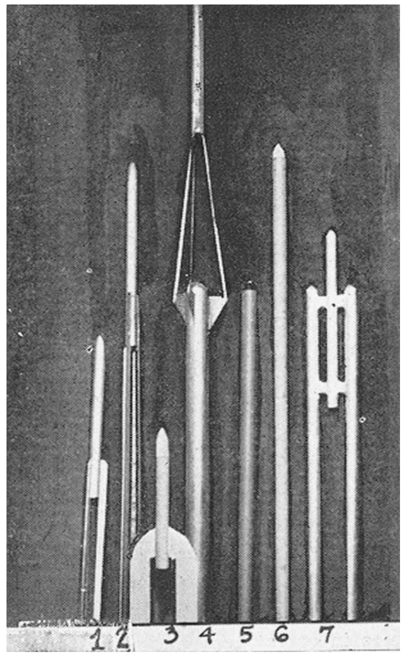


Fig. 20 Configurations tested in the first series of stability tests (No. 38, p. 10), Africano.

From late 1937 through 1939 the experimental committee carried out a series of solid rocket motor launches consisting of rockets of various shapes and sizes. These rocket tests were to determine the most suitable configuration for a rocket in regard to its stability. The actual flights took place on 12 September 1937 at Pawling, New York, and on 10 September 1939 at Mountainville, New Jersey. The configurations tested during the first series of tests are shown in Fig. 20 with the results shown in Table 8. The rockets were constructed by H. F. Pierce using balsa wood and fitted with solid rocket motors, 4-lb rocket skyrockets, with aerodynamic attachments such as fins to test the vehicles stability in flight. Each of the skyrockets weighted 12 oz, of which 6 oz was gunpowder. The configurations were based on rocket designs proposed by society members. The second series of stability tests were based in the data obtained from the initial tests. A series of new rockets were flown with various sizes of solid motors; 2-, 4-, and 6-lb rockets were used. These sizes equate to approximately 2, 4.8–6, and 10 oz, respectively. Figure 21 is a photograph of one of the stability test rockets in flight.

Proving stand no. 2 was unveiled on 22 October 1938 with a series of preliminary rocket motor tests at New Rochelle, New York. Proving or test stand no. 2 was designed by John Shesta with the

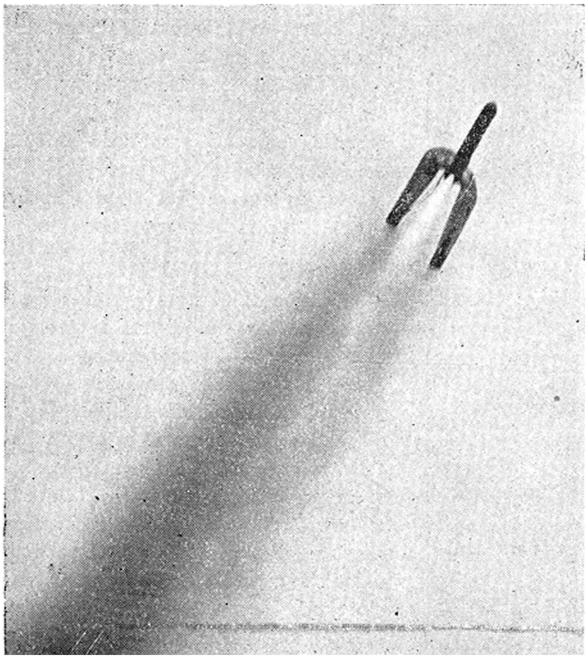


Fig. 21 Flight of a stability test rocket (No. 44, p. 1), W. Eugene Smith.

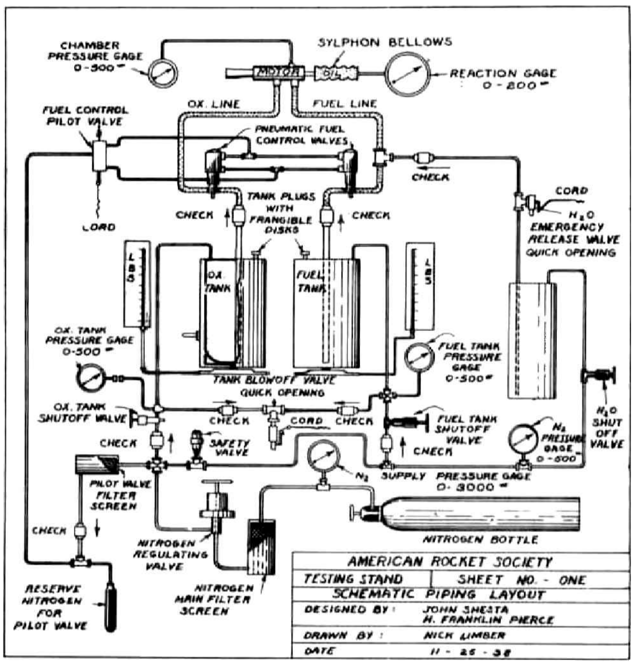


Fig. 22 Diagram of test stand no. 2 (No. 42, p.1).

knowledge gains from the tests run using the first test stand. A schematic or diagram of test stand no. 2 is shown in Fig. 22. This stand had a pneumatic system for operation of the fuel and oxygen valves, a constant feed nitrogen feed system, and a hydraulic tank-weighing device. The stand also incorporated a water flush system to cool the motors. A drawback of the new stand was its weight 300 lb, and so it required special carrying handles and a trailer for transport. The stand was instrumented, as seen in Fig. 23, with the following: the bottom row of gauges show the chamber and tank pressures with the upper row showing the pressure regulator, reaction or thrust, and clock; a gauge glass on the right gives the tank weights while the motor is mounted on the top of the stand firing to the side; and guide wires were attached to the stand to keep it from toppling or moving as the previous stand did. This stand was a vast improvement over the previous one. Figure 24 shows the back of the stand. The initial tests run on october 22 were check-out runs of the stand using a motor designed by Franklin Pierce for the tests;

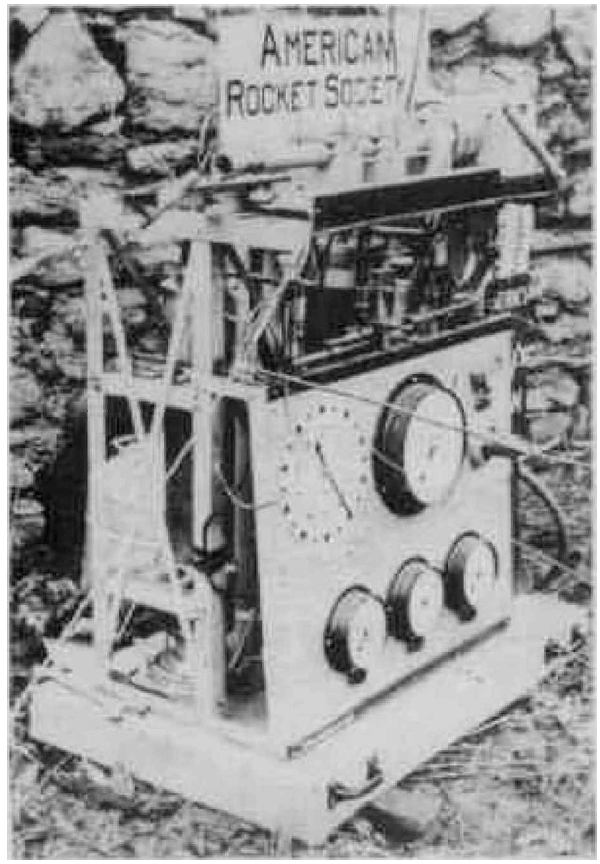


Fig. 23 Photograph of test stand no. 2 (No. 42, p. 2).

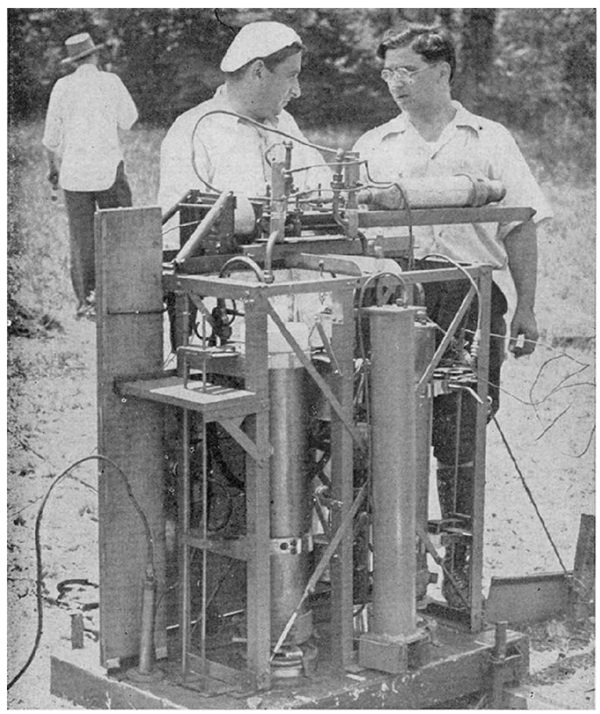


Fig. 24 Test stand no. 2 (No. 50, p. 1), Hecht.

the committee had studied various methods for igniting the motor and determined the shortcomings of the stand. The problems with the stand were corrected for the next series of tests. The clock was replaced with an electric one allowing better timing. A new larger cylinder for the oxygen valve was made because of sticking on the first trials, and larger powder fuses were used.

The committee ran the second series of motor tests on 10 December 1938 using three motors. Initially they tested the Pierce motor from the previous test, modified with a baffle plate to promote mixing. Approximately 90 lb of thrust was measured before a seam burst and the motor was cut off. The next motor tested was the Wyld regenerativiely cooled motor. This motor of tubular construction had a 2-in. internal diameter, 6-in. chamber length, $1\frac{1}{2}$-in. nozzle length, $\frac{5}{8}$-in. throat, and 1-in. exit diameter. During this initial test, the motor failed to combust. A second test was run after the final motor.

Next the committee tested another regeneratively cooled motor designed by R.C. Truax of the U.S. Naval Academy. This motor was constructed of steel about 18 in. long with a long slender combustion chamber 1 in. in diameter and 10 in. long, feeding an 8-in. nozzle with a $\frac{3}{8}$-in. throat and $1\frac{1}{4}$-in. exit diameter. A jacket was fitted around these internal components. The fuel flowed through this jacket from the motor head toward the nozzle then returned to the combustion chamber via two tubes connected to two $\frac{1}{32}$-in. ports near the throat. The oxygen was injected about 2 in. from the fuel ports into the combustion chamber. A fuse was screwed into the head of the motor used for ignition. The motor started off well, but then the side of the motor burned through. Upon examination it was concluded that some of the fuel vaporized, not allowing the free flow of the fuel to cool the motor.

The Wyld motor was retested. A metering nozzle in the alcohol line was replaced with a smaller one to provide a leaner mixture using a fuse for ignition along with some supplemental black power in the nozzle; the motor produced 90 lb of thrust for 13 s. until the oxygen ran out. The data from this test are shown in Fig. 25.

The experimental committee also tested a series of skyrockets for altitude on 19 November 1939. The rockets were donated by the Unexcellerated Fireworks Company and were of 2-, 4-, and 6-lb sizes. These commercial firework skyrockets obtained altitudes higher than the rockets from the stability tests in part because construction, that is, weight and possibly launch method. The stability rocket used a launch rack. Data from the commercial powdered rocket test flights are shown in Table 9.

In early 1940 the ARS Experimental Committee under Shasta modified proving stand no. 2 to provide longer runs of the motors and more accurate data to be obtained from the tests. The first use of the new and improved stand was on 8 June 1941, in Midvale, New Jersey. These tests were followed a few weeks later by another series of tests on 22 June 1941. On June 8 two motors were tested: Wyld's regeneratively cooled motor and a concentric feed design constructed by Nathan Carver and Charles Piecewiez. Figure 26 shows James Wyld holding his regeneratively cooled rocket motor. The experimental committee was becoming an old hand at motor tests. A dry run was made of the proposed test, and then the real tests were run. Because of problems in supply, liquid air was used instead of liquid oxygen. The Wyld motor fired first. It ran well, then started to chug during the middle of the run and finally ran out of fuel. The motor produced between 80 and 85 lb of thrust during its 26-s run. Upon examination of the motor, no damage was found. The Piecewiez motor was designed without a nozzle. The motor consisted of a small chamber where oxygen was injected in the top center while the fuel was sprayed into the oxygen by an annual nozzle to promote mixing. The mixture then passed through an 8-in.-long tube of $\frac{1}{2}$-in. diam before exiting the motor. The motor thus had no conventional nozzle. The purpose of the motor was to show that a conventional flared nozzle was not required. When the motor was ignited, a large brush of flame appeared at the end of the motor. It was observed that combustion was taking place outside the motor. Combustion lasted for 8 s with a maximum thrust of 42 lb.

Table 9 Skyrocket test flights

Shot no.	Rocket size, lb	Height, ft
1	2	Lost
2	2	506
3	2	624
4	3	779
5	3	769
6	3	730
7	4	892
8	4	861
9	4	830
10	6	1083
11	6	825
12	6	803

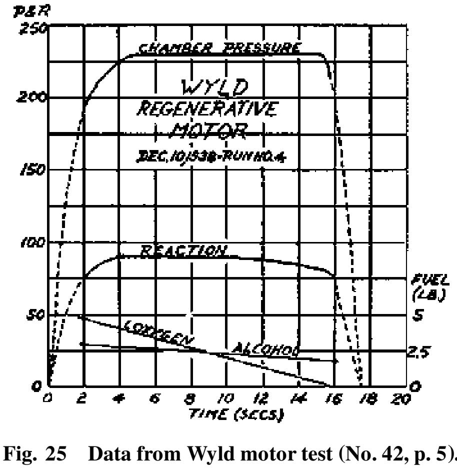


Fig. 25 Data from Wyld motor test (No. 42, p. 5).

Fig. 26 James Wyld and his motor (No. 49, p. 3), Greene.

A series of motors were tested on 22 June 1941, resulting in new testing records for the ARS. Motors constructed by Africano, Pierce, and Robert Youngquist were tested. Youngquist was from the MIT rocket club, an affiliate of the ARS. The Africano refractory lined motor reached a peak thrust of 260 lb while a small liquid-cooled unit ran for 48 s. The Youngquist motor on its final run exploded. The Africano motor was tested first. The motor consisted of a 15 lb of wrought iron pipe with a refractory or ceramic lining. The nozzle cone angle was 6 deg, with the diameter varying from $\frac{15}{16}$ in. at the throat to $1\frac{1}{2}$ in. at the exit plane. The nozzle was designed for a chamber pressure of 172 psig. The motor produced an estimate 280 lb of thrust. This is the estimate because the reaction gauge was calibrated at 200 lb at $\frac{3}{4}$ turns; the indicator hand pegged out on the stop at the full turn. The average reaction for 12 s was 184 lb of thrust. During the run, the ceramic lining was ejected out of the nozzle. No accurate estimate could be made as to the performance of the motor as a result of the changing parameters during the test. It was concluded that further testing of this type motor was warranted. The second motor tested was the MIT motor design and constructed by Youngquest and the MIT Rocket Club. The motor was designed to use the liquid oxygen to cool the lower half of the chamber and the nozzle. The oxygen was then passed through the jacket and sprayed

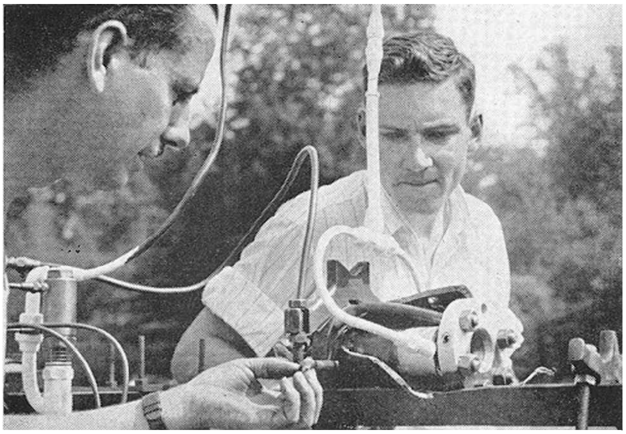


Fig. 27 Motor after firing test and explosion (No. 50, p. 5), Hecht.

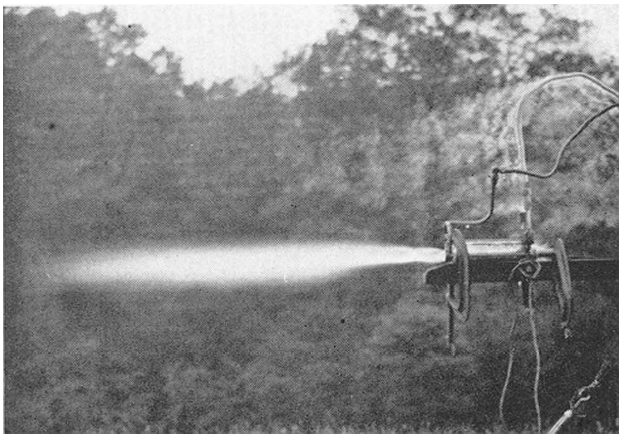


Fig. 28 Wyld motor test (No. 50, p. 8), Hecht.

upward into the chamber where a similar spray of the fuel was done to mix the propellants. The motor fired well for the first 13 s. producing 35 lb of thrust, but then exploded without warning, the cause unknown. Figure 27 shows the motor after the explosion at the conclusion of the test run. The final test was of a historic motor type designed by Franklin Pierce of the egg drop shape initially used on ARS rockets no. 1 and 2. A sheet-metal water jacket surrounded the motor for cooling. The motor produced a thrust of 35 lb and ran for 48 s, the longest run to date.

The most significant contribution of the motor tests was the tests involving the Wyld motor. This motor invented and developed by James H. Wyld, a 28-year-old physics graduate from Princeton University, was the first functional regeneratively cooled motor. The motor used the rocket's own fuel to cool the body of the motor erasing the need for a heavy water jacket or other expensive method of cooling of the motor. The cooling of the motor was needed to prevent a melt through of the motor walls. Figure 28 shows the motor being fired.

The Wyld Motor was again tested on 1 August 1941. Three runs of the motor were made using oxygen as compared to liquid air in the previous test. A thrust of 125 lb was achieved during the tests with a tank and chamber pressure of 250 psi. The initial run used 12 lb of propellant resulting in a firing time of 21.5 s. The second run using the same propellant load lasted for 23 s. The final run using the remaining oxygen lasted 45 s and produced a maximum thrust of 135 lb. This series of tests were a resounding success. The ARS stated, "The tests proved conclusively that a reliable motor for aerological sounding rockets has at last been designed, built and tested."[37] The motor was better than any other motor tested, but this test would be the last ARS rocket motor test. The societies experimental period would end on a high note.

Wyld, Pierce, Shasta, and a new society member, Lovell Lawrence Jr., decided they would develop Wyld's regeneratively cooled motor. The group formed Reaction Motors, Inc. (RMI), at the urge of the U.S. Navy on 18 December 1941. The Navy would not provide contracts or funding to individuals but would to a company. The Navy had witnessed tests of the motor and was interested in the application of the technology to rocket assisted takeoff for heavily loaded seaplanes. The company was initially located in Pompton Plains, New Jersey, near the former ARS proving area. RMI would later go on to develop numerous engines that would power the Bell X-1 and the X-15 along with numerous rockets, the Navy Viking, and missiles.

The society allowed RMI to use the test stand for their rocket motor tests. On 16 April 1942, the ARS board of directors officially loaned test stand no. 2 to RMI under the auspices of advancing technology with the clause that if any member needed to use the stand they could do so. This six-month initial loan would end up being indefinite. No further mention of the stand is made in the ARS files. The transfer or indefinite loan of this stand would officially end the experimental work of the ARS.

Epilogue: Work of Robert Goddard

Today Robert Goddard is considered the father of modern rocketry, although during the 1930s and 1940s he was the elusive leading expert in rocketry. In 1926 Goddard launched his first liquid-fueled rocket, which traveled 41 ft in altitude, 184 ft downrange in 2.5 s before the engine burned through. This was the first liquid-fueled rocket launched in the world. By December of 1930, one of Goddard's rockets had reached an altitude of 2000 ft; the IAS was barely six months old and had yet to start an experimental program. In 1937 Goddard's L-13 rocket, which was 9 ft long and 197 in. diam, reached an altitude of 9000 ft. Goddard's final launch was on 8 May 1941 with his pump-fed rocket P-31. In the September 1945 issue of *Astronautics*, the ARS published a fitting eulogy and summary of Goddard's work:

> With the death on August 10, 1945, of Dr. Robert H. Goddard, American science has lost one of its greatest pioneers—the creator of the modern science of rocketry. Even more impressive than Dr. Goddard's technical skill and ingenuity was his extraordinary perseverance, patience and courage in carrying on his investigations in the teeth of public skepticism and indifference with limited financial resources, and in spite of heartbreaking technical difficulties—a combination of obstacles which might have baffled and disheartened a less stout-hearted pioneer. Almost single-handed Dr. Goddard developed rocketry from a vague dream to one of the most significant branches of modern engineering.

The lifework of Dr. Goddard, as both a scientist and a man, will always remain a brilliant inspiration to all of those who are privileged to carry on his endeavors, and to every other bold explorer on the new frontiers of science. In time to come, his name will be set among the foremost of American technical pioneers."[38]

The ARS in 1960 erected a monument in Goddard's honor at the site of the first liquid rocket launch in Auburn, Massachusetts. After Goddard's death Mrs. Goddard filed for an additional 131 patents, bringing Robert Goddard's total patents to 214; in 1906, she was granted a million-dollar settlement from the U.S. government for use of Goddard's patents.

Society Membership

In the prewar years the society membership overall grew but had its ups and downs as the society evolved from a group of writers dreaming of the concept of promoting space flight to a society driven with the advancement of the science of rocketry and jet propulsion. As the popularity of rocketry increased along with the technical capabilities of the industry, so did society membership. The advent of World War II and its aftermath had a marked increase in interest in rocketry and membership in the society. Table 10 provides a summary of membership in the society from its beginning in 1930 through 1947. Data were not available for all years.

Merger ARS/IAS

In 1963 the American Rocket Society merged with the Institute of the Aerospace Sciences.[39,40] The merger was brought about by the increased overlap in the coverage of the two societies. Both the

Table 10 Membership in the American Rocket Society 1930–1947

Year	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Active	10	N[a]	N	23	21	25	N	32	32	32	33	35	33	34	50	51	107	204
Associate	——	N	N	62	34	56	N	66	67	73	89	131	121	171	220	221	328	462
Junior	——	——	——	——	——	——	——	——	1	1	7	17	23	26	44	46	72	93
Affiliate	——	——	——	——	——	——	——	——	——	7	12	21	23	20	20	ND[a]	ND	ND
Total	10	64	N	85	55	81	N	98	100	113	141	204	200	251	334	318	507	759

[a]N, ND = no data available.

IAS and the ARS were targeting and servicing the same interest areas and members, notably jet propulsion and rocketry. With the advancement of technology, the institute needed to expand into the realm of space. The Institute was founded in 1932 as the Institute of the Aeronautical Sciences and had its initial founders meeting and 1st annual conference in January 1933. Subsequently, over the years it became the premier aeronautical society in the United States with a list of members that served as a who's who of the aerospace industry.

Conclusions

The year 2000 marked the 70th anniversary of the founding of the American Interplanetary Society by a group of 10 enthusiasts with pursuits on interplanetary travel. From these humble beginning the society has steadily grown through the American Rocket Society years to the 1963 merger with the Institute of Aerospace Sciences into the premier aerospace society in the United States, the American Institute of Aeronautics and Astronautics (AIAA.) The fledgling society grew out of the ideal to promote interplanetary travel or the conquest of space to more down-to-earth ideals, the advancement of jet and rocket propulsion. These ideals led to the early experimental programs of the society. The rockets in themselves did not greatly advance the state of the art in rocketry but did lead to the technical development of individuals who would contribute to the advancement of rocketry and the space program. The Wyld motor is one such case. The early years of the society and its experiments should be remembered for two major contributions to the advancement of rocketry: 1) the dissemination of information regarding rocketry through the bulletin and journal and 2) the opportunity given to a group of individuals to advance their technical abilities. Those early experiments might be forgotten, but the advances fostered by these early experimenters and their later works will be remembered.

Appendix: Brief Chronology of ARS Experiments

21 March 1930	Founding of AIS
12 November 1932	Test of AIS rocket no. 1
14 May 1933	AIS rocket no. 2 launch
6 April 1934	Name change to ARS
10 June 1934	Preliminary ground tests ARS rocket no. 4
9 September 1934	Launch ARS rocket no. 4
9 September 1934	Ground tests of ARS rocket no. 3
21 April 1935	New proving stand motor tests
2 June 1935	Second crestwood proving stand motor tests
25 August 1935	Third motor tests with alcohol, motor overturns, and explodes
20 October 1935	Fourth motor tests, woman injured after test
22 June 1936	Notification of winning REP-Hirsch prize
12 September 1937	Pawling stability rocket flights
22 October 1938	New rochelle rocket motor tests using proving stand no. 2
10 December 1938	First test of wyld's motor
10 September 1939	Mountainville rocket stability flights
19 November 1939	Commercial skyrocket test flights
Early 1940	Proving stand no. 2 modified
8 June 1941	Midvale motor tests using modified stand no. 2
22 June 1941	Motor tests
1 August 1941	Wyld motor tests—last ARS rocket test
16 April 1942	Test stand loaned to Reaction Motors, Inc.

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