History of Rocketry and Astronautics

Proceedings of the Forty-Second History Symposium of the International Academy of Astronautics

Glasgow, United Kingdom, 2008

John Harlow, Volume Editor

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AAS History Series, Volume 39

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 28

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 2013

ISSN 0730-3564

ISBN 978-0-87703-589-3 (Hard Cover)
ISBN 978-0-87703-590-9 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198
Web Site: http://www.univelt.com

Printed and Bound in the U.S.A.

Chapter 5

James H. Wyld (1912–1953): American Rocket Pioneer and the Development of the Wyld Regeneratively Cooled Rocket Motor*

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Abstract

James Hart Wyld, born in New York City and of Scottish heritage, is one of the great pioneers of U.S. rocketry. But surprisingly little has been written of his biography and the history of his invention even though a crater on the far side of the Moon is named in his honor. Wyld was responsible for inventing, building, and testing the first successful U.S. regeneratively cooled rocket motor between 1938 and 1941, and in 1941 he was one of the four founders of Reactions Motors, Inc. (RMI), the U.S. first liquid-propellant rocket company. (Figure 5–1).

RMI used the Wyld regenerative principle to develop among the first U.S. liquid propellant JATO (Jet-Assisted Take-Off) rockets for aircraft, missile motors, and the 6000C-4 motor (also known as "Black Betsy") that powered the Bell X-1 aircraft that broke the sound barrier in 1947.

Thus far, the most definitive biographical treatment on Wyld is the two-part article, "Princeton's Rocketry Pioneer" by George F. Bush, in *The Princeton Engineer* (Princeton University, Princeton, New Jersey), for December 1968 and January 1969, respectively. However, this journal is somewhat obscure and diffi-

* Presented at the Forty-Second History Symposium of the International Academy of Astronautics, 29 September – 3 October 2008, Glasgow, United Kingdom. Paper IAC-08-E4.2.02.

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cult to find. The author of these articles, a close friend of Wyld who had known him while both studied at Princeton University, intended to publish a full-length biography, also to be titled *Princeton's Rocketry Pioneer*, but this project was never completed.

Figure 5–1: James Hart Wyld (1912-1953), American rocket pioneer, designer and builder of the U.S.'s first successful regeneratively-cooled rocket motor and one of the four founders of Reaction Motors, Inc. (RMI), the U.S.'s first liquid-propellant rocket company. Photographed by Walter Scott Shinn, New York, ca. 1930s. Interestingly, Shinn was a well known photographer who had also taken photos of the likes of Thomas Edison, Theodore Roosevelt and family, and the actress Clare Boothe Luce. Smithsonian Photo A4064.

The present chapter thus draws from the Bush articles but mainly uses primary source material, including Wyld's original correspondence, a diary, notebooks, and newly discovered photos, and is an effort to ensure that Wyld and his motor are better known, especially within the astronautical community. Also presented here are important newly found facts on the earliest regeneratively cooled rocket motor of Robert H. Goddard.

Childhood

Although Wyld's birth year is often cited incorrectly, even in the citation on him for a crater on the far side of the Moon named in his honor, his own typed vitae found in the archives of the National Air and Space Museum (NASM) in Washington, DC, shows that he was born in New York City on 10 September 1912. He was the son of Robert Hasbrouck Wyld, a gifted mechanical engineer in his own right who became the Vice President of Burns and Roe, Engineering Consultants of New York. The young Wyld was a reserved and highly intelligent individual with wide-ranging interests. There are also documents in his file that indicate that his forebears might have been Scottish. Most notably, one of them is a genealogical list of the "Scottish Royal Family."* Bush also relates that Wyld was a child prodigy who learned to read largely on his own at age four and proceeded to read the 20-volume *Book of Knowledge*, cover to cover several times. His special interests and abilities came to include writing (both prose and poetry), languages, debating, acting, sports, astronomy including telescope-making, radio, aviation, and magic.[1]

Wyld's parents recognized his gifts and provided him with a private tutor for three years. He attended the Harvey School at Hawthorne, New York, a prep school from which he graduated in 1928. He then went to Salisbury School, a boarding school for boys in northwestern Connecticut, then entered Princeton University in 1931, graduating in 1935 with a Bachelor of Science in Engineering in Mechanical Engineering with High Honors, then undertaking postgraduate work from 1935 to 1936 in Electrical Engineering at Princeton under a Sayre Fellowship.[2]

Wyld's Introduction to Rocketry

There are varied accounts on how Wyld became introduced to rocketry. According to his recollections, he wrote for the December 1951 issue of *The RMI Rocket,* which was then commemorating the tenth anniversary of the company, he first became fascinated with the possibilities of spaceflight when he read David Lasser's *Conquest of Space*, published in 1931 as the first English-

* The writer of the present chapter recalls that there were other documents in this file that more directly link Wyld to Scottish forebears, although unfortunately these particular documents are now missing. In any case, the previously seen documents were sufficient for the writer to describe Wyld as of "Scotch [*sic*]–Irish ancestry," in the article "Bringing Up Betsy" in *Air and Space* magazine for January 1989. However, this matter was finally settled a day before this paper was presented by an unexpected cell phone call to the author by Robert L. Wyld, the son of James H. Wyld, who said that his father's forebears came from the village of Gilston, in East Lothian, Scotland, 16 miles (26 km) east of Edinburgh.

language work on the subject. "The margins of my college engineering texts for several years afterwards," he said, "acquired a border for crude sketches of rockets motors. . ." However, in his diary, he wrote that during that period he was then "only dimly aware of the experimental work being done." "I think my first active interest [in this aspect of rocketry]," he added, "was in the spring of 1934, when a picture of Ernst Loebell, Pres.[ident] of the Cleveland Rocket Society, with an experimental rocket motor was posted in the window of a local bank (one of a series of 'news events' cards. It aroused my interest, and I actually wrote (but never sent) a letter to Loebell asking for a job in connection with the Cleveland Society's work." Then, in the fall of 1934, "my interest flared up again on reading an article 'Men of Space' by Ugo Andres, in the *New Outlook* magazine for Oct. 1934." (At the same time, according to Baum, he also borrowed the book *Raketenfahrt* [*Rocket Travel*] by Max Valier from a college professor.)[3]

In actuality, "Andres" was a pseudonym for G. Edward Pendray, one of the founders, in 1930, of the American Interplanetary Society (AIS) that changed its name to the American Rocket Society (ARS) in 1934; from 1934 to 1936, Pendray served as the Society's President. Naturally, he described the Society and its work in his article that prompted young Wyld to look up the organization in the New York phone directory. He eventually wrote the organization a letter, which was forwarded to Pendray. He explained he was interested in the Society's work "especially the actual experiments, and had good mechanical training which would come in handy. . ." This was in 1935. As a consequence of his discovery of experimental rocketry, he added, his life was now "completely changed around."

The ARS had started its rocketry experiments in 1932, although the group's few members were young idealists and mainly science fiction fans rather than engineers. They had no clear long-range goals in their rocketry work, just the vague mindset that "interplanetary flight" could only be accomplished by the rocket, and that they might somehow help lay the technological foundations toward this lofty goal. Apart from this, because these were the earliest years of the worldwide economic Depression, their experiments were conducted on shoestring budgets. Consequently, their experiments were rudimentary, and between November 1932 and September 1934 they launched but two liquid fuel rockets, the last one only up to 116 meters (382 ft) as ARS No. 4. The Society soon reached the conclusion that more meaningful technical data could be gained from static tests on a test stand and that, in the long run, this approach was more practical from the budgetary standpoint.[4]

Work was thus initiated on the design and construction of their first stand, known as Test Stand No. 1. The first series of runs was made on 21 April 1935 at

Crestwood, New York.* Wyld attended the fourth series of tests with ARS Stand No. 1 on 20 October 1935, which was probably his first exposure to the experimental side of rocketry.[5]

By far, the most serious technical problem encountered by the experimenters was the overheating of their tiny rocket motors. Among the various methods of cooling tried were water jackets, aluminum "heat sponge" blocks, and heat-resistant materials, such as Nichrome. But water cooling, they found, worked on smaller motors, although it was too heavy and ineffective for larger ones. Aluminum blocks were cumbersome and heat-resistant materials generally did not survive long runs. One technique that helped involved cooler-burning fuels. For example, alcohol burned more smoothly than gasoline, and, when diluted with water, it slightly cooled the engines.[6]

From early March 1935, about two or three weeks before Wyld applied for ARS membership, he was already engaged in studies on rocketry, although he did not fully concentrate on cooling methods as yet. At this point, following a suggestion made by Professor Louis Rahm of Princeton's Engineering School, he teamed up with William E. ("Bill") Rahm, Jr., the professor's nephew and a fellow engineering student, who was likewise intensely interested in rocketry. Shortly thereafter, Princeton's Astronomical Observatory Professor John Q. Stewart, one of the few academics who then publically championed the cause of spaceflight when it was not an altogether "respectable" subject, gave the two students permission to use the observatory basement as their base of operations. But, he warned them *not* to shoot off rockets inside the building. They thus proceeded toward planning to build an experimental liquid oxygen [LOX]/gasoline, nitrogen, pressure-fed rocket that could be launched from the University's outside stadium. Rahm, as told to Bush, later recalled that they made some preliminary studies on nozzle design while thrust calculations were made by Professor Rahm.[7]

All the while, Wyld closely informed Pendray and others of the Society of every detail of his progress and many of his ideas. He was an incredibly prolific letter writer who wrote in a distinctively clear style in long-hand pencil, usually on yellow legal-size pads. His extant letter to Pendray of 27 April 1935, for example, amounts to 26 pages, including sketches, was actually written over several months. In this letter, he reported that he was working on the "fittings for the rocket," including the tanks, while Rahm was "seeing about getting the combus-

* Unlike their earlier German counterpart, the Verein für Raumschiffahrt (VfR), also known as the German Rocket Society, the ARS never had a fixed research station and only conducted its static tests with a portable stand set up on vacant fields and the like, ever watchful for fire inspectors. In the case of Crestwood, they felt fairly safe, as it was in a field adjacent to Pendray's house.

tion chamber made." They had also completed intake valves on ARS member John Shesta's design. The nozzle was to be of heat-absorbing aluminum alloy and "cast for us by a friend at Lafayette College ... while the bottom part of the chamber was to be of steel." "We have not definitely decided whether to put air-cooling fins on the nozzle and chamber base," he added, although he observed that "air-cooling fins is [*sic*] simplest but offers [*sic*] constructional difficulties..." Still other possible cooling schemes included the cutting of a fine thread "all over the inside of the combustion chamber and ... tamping in fine carborundum powder ... to provide a thin layer of insulation close to hot gases..." "However, he concluded, "... the real solution [to cooling] lies in the use of a good heat-resisting alloy like Nichrome or Durron or Stellite." He considered tungsten and beryllium, although noted their great expense.[8]

In part of his letter to Pendray written on 5 June, Wyld briefly mentioned the rocket motor of Harry Bull of Syracuse, New York, who (in 1933–1934) "made some runs as long as two minutes with motors of ordinary mild steel..." Later, he learned that Bull had achieved this then remarkable duration because his motor was partly regeneratively cooled. The remainder of Wyld's marathon letter covers everything from his concepts of gyroscopic stabilizers in the fins and streamlining, to parachute gears and improved propellant feeding. There is also the interesting quote that: "I am a great *re*-inventor [*sic*] of rocket improvements, it seems! Rahm between us thought of about half a dozen things that had previously been invented, among them: ceramic linings, solid ceramic combustion chambers . . . [and] radio for following [a] rocket in flight, and photo-triangulation for plotting path of flight." He concluded with the suggestion that he and Rahm form a Princeton Rocket Club, although nothing came of this.[9] *

In his letter to Pendray of 19 June 1935, Wyld remarked that, "Unfortunately, rocket-building at Princeton has been in abeyance for some time, owing to final exams, graduation ceremonies ... and I am ill-provided with machine tools."[10]

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* Here, it is relevant to point out that throughout this, and most other Wyld letters, no mention is made of the work of Robert H. Goddard, then considered the country's preeminent rocketeer. The underlying reason is Goddard's secrecy. Goddard provided too few engineering details in his *Liquid-Propellant Rocket Development* of 1936. For example, in the review of this work in the ARS journal *Astronautics* for June 1936, Peter Van Dresser observed: "His paper is more in the nature of a general description of his work ... and leaves the reader eager for more specific information of an engineering or mechanic nature." It was not until long after Goddard's death, that *The Papers of Robert H. Goddard* appeared in 1970 which more fully revealed the extent of this pioneer's great—if previously hidden—technological achievements.

Background of the Regenerative Motor

According to his later recollections in the December 1951 issue of *The RMI Rocket*, Wyld wrote: "I cannot now recall where I picked up the idea of cooling a rocket regeneratively; it was not original with me, of course. And one major source of inspiration was the early work of Eugen Saenger [or Sänger] at the Vienna Technical College in 1933–1934, which I learned about through a fellow member of the [American] Rocket Society, Peter Van Dresser."[11]

Sänger's widow, Dr. Irene Sänger-Bredt, and Rolf Engel, wrote a now classic International Astronautical Federation (IAF) paper, "The Development of Regeneratively Cooled Liquid Rocket Engines in Austria and Germany, 1926-42," in which they offer a basic definition of the regenerative cooled rocket system: "In a regenerative cooling scheme . . . the coolant is a propellant or working fluid and part of the propulsive energy supply system. The heated coolants fed into the combustion chamber, are not wasted; they aid in processing for combustion." That is, the preheated fuel aids in the combustion besides cooling the motor.[12]

Sänger-Bredt and Engel also thoroughly documented the ground-breaking, pioneering rocketry experiments of Eugen Sänger in 1933 using regenerative cooling, so there is no need to recount them here. They also cover the earlier theoretical cooling methods of Hermann Oberth in 1923 in his seminal work, *Die Rakete zu den Planetenräumen* (*The Rocket into Planetary Space*), which they characterize as "inner dynamic regenerative cooling." However, only scant attention is paid to the theoretical work of the Russian pioneer Konstantin E. Tsiolkovsky and the American experimenter Robert H. Goddard, while Wyld is not mentioned at all. In the case of Tsiolkovsky, they do credit him with a design in 1928 "embodying at the same time dynamically and regeneratively cooled combustion chamber." In the case of Goddard, they state that in his *Liquid-Propellant Rocket Development* (1936) he "does not even mention cooling methods" and that his "first treatments of cooling methods are found in the U.S. patents 2,016,921, 8 October 1935, 'Means for Cooling Combustion Chambers,' and 2,122,521, 5 July 1938, 'Cooling Jacket Construction.'" However, for some unknown reason Sänger-Bredt and Engel do not examine these patents. Yet, according to Esther C. Goddard, Lovell Lawrence of RMI identified the latter patent as covering "regenerative cooling" and was even "infringed by many companies as early as 1952."[13]

George P. Sutton, in his *History of Liquid Propellant Rocket Engines* (2006), notes that in one of Tsiolkovsky's early sketches of a rocket-propelled space vehicle, "a part of the oxidizer flow is used as a coolant for the vehicle, presumably for reentry protection." Sutton does not date this sketch but he adds that Tsiolkovsky's "suggestion to use propellant ... as a ... coolant was taken seriously by the Russians because they were one of the first to use cooling jackets and regenerative cooling in early LPRE [Liquid Propellant Rocket Engines] in the early 1930s." Elsewhere in his book, Sutton specifically identifies the ORM-50 rocket engine in the Soviet Union that was regeneratively cooled and tested in 1933 and mentions that other regeneratively cooled engines were tried in the Soviet Union up to 1937. He additionally notes (as is also covered by Sänger-Bredt and Engel) that by 1933 the VfR, or German Rocket Society, "had started work on a regenerative fuel-cooled thrust chamber in the 300- to 450-lb [136–204 kg] thrust range [as part of Project Magdeburg], several years before the United States tested one. However, the work of the VfR was suspended because of financial [and other] problems." He also credits Wyld who "designed and tested the first regeneratively cooled thrust chamber in the United States in 1938." But was Wyld really the first, or was it Goddard?[14]

Goddard's Regeneratively Cooled Rocket Motor

Fortunately for historians of rocketry, during the mid-1960s in preparation for his 1968 IAF paper "Robert H. Goddard and the Smithsonian Institution," Frederick C. Durant III, then the Assistant Director of Astronautics at National Air and Space Museum, spent considerable efforts to try to answer this question. The end result resulted in a letter of 3 April 1965 from Goddard's widow, Mrs. Esther C. Goddard, to Dr. Eugene M. Emme, then the NASA Historian. Mrs. Goddard quoted from a report of 1 August 1923 by Dr. Goddard to the Trustees of Clark University (then financing his rocket work). Dr. Goddard described "a jacket ... outside the chamber and nozzle ... the liquid oxygen being pumped into the bottom ... between the jacket and the chamber-nozzle ... [and] the ether [the fuel] being introduced axially through the opening. . ."[15]

To this, Goddard added, "This chamber has been used ... in a preliminary run, March 9, 1923." He also sent the Trustees a photo with the following notation: "First jacketed chamber, used in early liquid-propellant rocket tests. Liquid oxygen passed in at bottom of jacket, and around curved inside at top of chamber. Gasoline or ether entered through the central hole. Important principle." Later, in November 1943, Dr. Goddard wrote a long report titled, "The Ultimate in Jet Propulsion," summarizing his work, in which he said: ". . . A *regenerative chamber* [my emphasis], in which the oxygen passed up around the nozzle and chamber and entered the latter at the head end, was given a preliminary test, on

March 9, 1923." He was thus the first in the world to build and test a regeneratively cooled rocket motor.[16]

However, there is no evidence that Goddard adopted this form of cooling. In fact, for most of his earlier work in the 1920s–1930s, he preferred water cooling, using longitudinal cooling tubes around the chamber. We can only speculate that water cooling was simpler for him to use. For many years, the National Air and Space Museum exhibited an example of this water cooling system. For his later experiments in the 1940s, according to Robert C. Truax, "Dr. Goddard's engines embodied film cooling, not regenerative cooling."* House says Goddard "satisfactorily" demonstrated film cooling in 1935. In any case, it is clear that throughout his life, Wyld himself knew nothing of Goddard's 1923 experiment nor much about his cooling methods in general. Nonetheless, to now set things into proper historical perspective, there is no question that Wyld's regeneratively cooled rocket motor was the first successful one in the United States, in that it was incorporated into mainstream rocketry, whereas Goddard's earlier, 1923, effort was only tried on a one-time basis and remained obscure.[17]

The Evolution of Wyld's Regenerative Cooled Motor

As mentioned, Harry Bull came up with a partly regeneratively cooled rocket motor and tested it during 1933–1934 that was later discovered by Wyld. In his letter to Pendray of 27 April 1935, Wyld surmised that Bull probably used large tanks to provide gas pressure to force in the fuel, and that his thrusts were low. These he saw as inherent weaknesses in Bull's approach. In fact, Wyld afterward identified Bull's propellants as gasoline and *gaseous* oxygen with consequently very small thrusts, and also noted that his "design had used regeneration for nozzle cooling only." Hence, he called it "partly regenerative."†

One direct but overlooked and crucial element in the history of the evolution of Wyld's motor was the ARS static test stand. In Wyld's letter of 19 June 1935 to Pendray, he observed: "I think the idea of providing testing stand facilities for trying motors ... by members of the Society is excellent—Hope to submit some concoction myself some time." But ARS Stand No. 1 was a crude affair, and the timing could not have been better for Wyld when Stand No. 2 appeared at about the time he was ready to test, although by later standards this equipment too was rudimentary. Only thrust, time of firing, and tank pressures—but not

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* Without knowing of Goddard's 1923 experiment, Truax was led to conclude that Wyld's 1938 motor was "the first [U.S.] regeneratively–cooled rocket motor."

† For further details on Bull's work see the paper on him by Winter.[18]

temperatures—could be read. Like Stand No. 1, No. 2 was portable and still exists and is currently on exhibit in the National Air and Space Museum. It is indeed, an integral part of the Wyld story. Nonetheless, in the same letter, Wyld informed Pendray that he had been "meditating a bit more on the subject of accurate metering of fuel..." "One method," he said, "would be to have a jacket surround the blast chamber into which liquid oxygen from the tank would flow and vaporize, the gas returning to the tank. A diaphragm or piston arrangement could be fitted which would cut off the flow when the pressure was sufficiently high..." The suggestion of a jacket around the chamber was close to Wyld's later regenerative system, but at this time he was not thinking about cooling.[19]

Wyld's letter of 26 June 1935 to Pendray presents useful formulae and graphs to calculate thrusts and curves to determine gas (exhaust) velocities. A letter of 4 October to Van Dresser offered a "Rocket Efficiency Formulae." Then, in a letter of 19 November to Van Dresser, he mentioned that he had "been devoting considerable thought to [fellow ARS member] Nathan Carver's idea of having a rocket motor without any combustion chamber, but merely a 'long combustion nozzle' in which combustion & expansion take place simultaneously." Wyld explained the principles and noted that a small chamber for a "fuel-preheater" was necessary and that this chamber "requires either (a) very violent turbulence (which you do *not* [*sic*] get in any of the conventional motors yet tested) or else (b) preheating the fuels entering the motor so as to cause them to fire with explosive rapidity when they strike one another, (that is, the temperature of spontaneous ignition must be reached.)" "...The nozzle," he added, "is fuel-cooled; in fact it must be fuel-cooled, since preheating of the fuel is the key to the whole process..."[20]

Adjoined to this is a sketch showing a long combustion chamber wrapped around with what he labeled as "fuel-heating tubes" (that is, tubes with fuel for preheating it prior to entering the chamber.) More elaborate sketches are on the following page on which he calls the tubes "coiled tubing," while the propellants are given as LOX and alcohol. Thus, there are important elements here *suggesting* (my emphasis) regenerative cooling. Much later, on 25 September 1941, Wyld wrote a 17-page report, entirely in pencil, titled "Wyld 'M-15' Regenerative Rocket Motor—Sketches, Notes, & Discussion." This important document goes into the engineering rationales of what he designates as his "M-15 Regenerative Rocket Motor." This is therefore not a history of his motor but does go into "prior art" in rocket cooling methods. As an example, he mentions the earlier "pre-heater" of Carver and Hugh Franklin Pierce that was proposed for ARS Rocket No. 5 (in *Astronautics* No. 27) for 1933 and also given in *Astronautics* No. 33 (1936), in Van Dresser's survey of motors. But in his report, Wyld also made it clear that the pre-heater "was not in connection with a cooling jacket..." Nonetheless, the term "cooling" was certainly suggested by Carver's pre-heater of 1936 and the coils do *surround* the chamber and therefore the pre-heater may well have helped trigger Wyld's mind into a focus on cooling and to soon come up with the cooling jacket that was the heart of his regenerative system.

But there is even more interesting evidence in the evolution of Wyld's thinking toward the regenerative system. Within the National Air and Space Museum Archives is another Wyld letter, although a partial one that was donated by Wyld's son, Robert, dated 28 January 1936. The recipient of the letter is unknown. In any case, it includes a sketch, and centers around the design of a sounding rocket seven feet long (2.13 m) and 3.5 inches (8.9 cm) in diameter, using LOX and alcohol and contemplated for a six mile (9.6 km) altitude. Wyld had not "computed the exact altitude yet" but stressed that "Everything depends on getting a motor that will stay together for a full minute and burn the fuel with maximum efficiency. The motor design is not yet entirely worked out, but is to have 'regenerative cooling' (alcohol is to circulate through a cooling jacket around the motor before entering the latter.) I am going to try to cast a nozzle in Molybdenum, but if this proves impractical we [Rahm and Wyld] will try something like Nichrome or Durel or copper." Hence, we arrive at the earliest known use of the term "regenerative cooling" by Wyld himself, with a brief description of it.[21] (Figure 5–2).

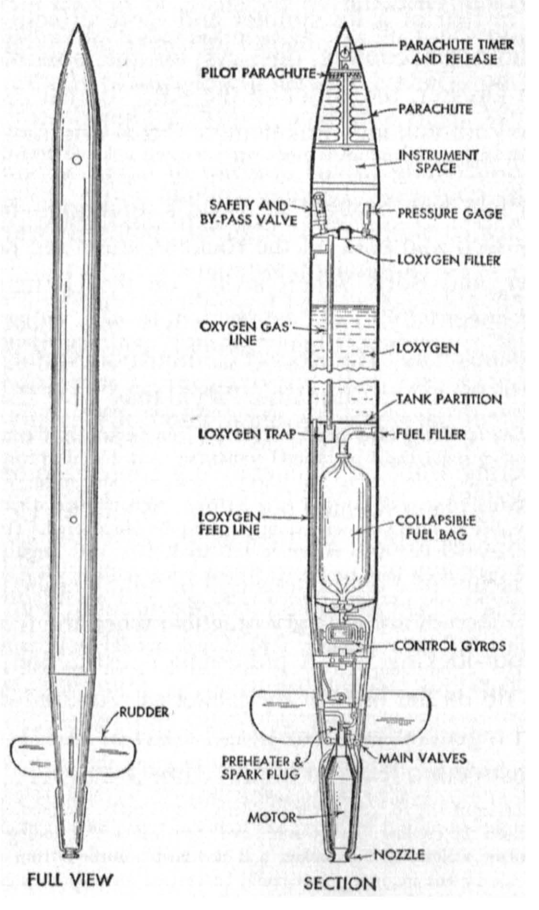

Figure 5–2: Drawing by Wyld of his concept of a meteorological sounding rocket, which he probably first conceived in 1935. The design incorporated several interesting features, but according to Wyld in a letter of 28 January 1936, "Everything depends on getting a motor that will stay together for a full minute and burn the fuel with maximum efficiency. The motor design is not yet entirely worked out, but is to have 'regenerative cooling'. . ." Thus, his sounding rocket idea was clearly a central motivation for working towards his motor. Smithsonian Photo 4561-C.

From the foregoing, it appears that Wyld most likely arrived at the regenerative motor concept at some time during late November 1935 to January 1936, which is earlier than previously believed, and that the idea may have been inadvertently started by his extended thoughts on the Carver "pre-heater." If it did happen this way, Wyld's brilliance and abilities cannot be denied, because he still had to arrive at the cooling jacket design, perfect it, bring the entire concept into fruition, and prove it. As later recounted in *Astronautics* (August 1939), he went through a dozen preliminary designs of the regenerative motor, worked out heat-transfer estimates derived from gas turbine tests, and carefully designed the mixing ports "to ensure proper mixing and proportioning [of propellants]." In fact, his "M-15" designation—that very likely simply meant "Motor No. 15"—seems to confirm that he indeed went through about a dozen designs until he reached the final version. A rare drawing and brief description of one of Wyld's earliest versions of his motor is given in Van Dresser's survey of rocket motors in his March 1936 article and shows what appears to be an incorporation of Harry Bull's combustion chamber configuration and Bull's cooling fins feature. But Wyld soon discarded both features in lieu of a lot simpler and more effective long cylindrical configuration, without the cooling fins. As for the possible Sänger connection, Sänger sent Van Dresser, the editor of the ARS journal *Astronautics*, a copy of his article "Der Verbrennungs-Raketemotor" that originally appeared in the journal *Schweitzer Bauzeitung* (*Swiss Journal of Construction*) for January 1936. Evidently, the article was brought to Wyld's attention—he knew both German and French very well and read all the rocketry literature he could, including Oberth, Max Valier, and Boris Scherchevsky on the German side, and Robert Esnault-Pelterie, respectively. The Sänger article was subsequently translated by Merritt A. Williamson as "The Rocket Combustion Motor," appearing in *Astronautics* (October 1936). At the same time, Wyld may have also been familiar with Sänger's book, *Raketenflug* (*Rocket Flight*) (1933) so that one way or another the Austrian's pioneering work on regeneratively cooled motors became known to him. In any case, Wyld later pointed out in his "Wyld 'M-15'" report that Sänger's 1936 article "proposes to cool a rocket motor (either regeneratively or by a special coolant) by means of a continuous coil of tubing embedded in the motor wall..." But, "Such schemes are not very practical when the fuel is vaporized, owing to danger of vapor-locking..." "A preferable construction," he concluded, "is the use of a spiral rib on the liner or the jacket as proposed in the first designs for the M-15 [Wyld regenerative motor] (early part of 1937)—the flat passage produced by this construction leads to improved heat transfer...

and the pitch of the spiral can be made to increase to provide for vaporization etc."*

Toward the Construction

Due to Wyld's schooling and employment, his motor developed slowly. In Van Dresser's survey of rocket engines in the March 1936 issue of *Astronautics* there appears, with a drawing, perhaps the earliest known version of Wyld's motor. While on 21 May 1936, in another partial letter to an unknown recipient, he sketched out a basic design and modestly stated that "... I may build a simple experimental rocket motor to try out on the Society's new proving stand, now under construction." In the following month, *Astronautics* ran his first rocket article, "The Problem of Fuel Feed," although with no mention of his new concept. But he was certainly excited about the concept when, during that same summer, he voyaged to Europe with friends Dwight C. Baum and Bill Harry in a small ship owned or managed by a Norwegian–Scottish relative of his. Besides the sights, he went to London to "advise Phil Cleator, President of the new[ly formed] British Interplanetary Society, on their experimental programs..." As remembered by Cleator, as told to Bush, Wyld and his friends were also taken to north Wales and witnessed the "substantial remains of King Edward Ist's famous castle" while another evening "was spent at the Grand Hotel on the seafront at New Brighton, throughout the whole of which Wyld regaled us with an account of his plans for a regenerative motor..."[23]

That October and later in March 1937, there appeared Wyld's second and third articles, "Fundamental Equations of Rocket Motion—Part I" and Part II in *Astronautics*, respectively, that cite Goddard, Esnault-Pelterie, Oberth, and Sänger. The latter issue also reported in "News and Notes" that in the winter meeting of the Society (that is, during the winter of 1936–1937) Wyld described his "new rocket design embodying ... fuel-cooled motor..." Then, in his letter of 20 March 1937 to an unknown recipient from outside the New York area, he confidently stated: "I have most of the material together for my rocket motor; it is all Dural, with an alcohol cooled jacket..." [Here, he inserted a sketch of the motor that was 10 in., or 25.4 cm long, and 2.5 in., or 6.3 cm in diameter.] "The fuel," he continued, "goes in around the nozzle on the outside, spirals up through the

* Interestingly, the extant Wyld documents do not mention Sänger's actual 1933 regenerative cooled experiments, although Wyld was very thorough, and it is possible that he did learn of them at one point but that the proof of his knowledge of them is lost. In any event, Wyld always acknowledged Sänger as a pioneer in regenerative cooling and helped inspire him and validate his own work.[22]

jacket, strikes the oxygen as it comes through ports at top motor, & is ignited by the spark plug . . . I don't know till I try it whether the spark plug will work at all, or whether it will just start combustion or whether it must work continuously all during the firing; also it may prove necessary to make the motor out of steel instead of Dural in order to stand the heat. This can only be found by trial."[24]

On 23 May, Wyld reported to Van Dresser that: "The work on my motor progresses, but very slowly. I am working at Nathan's place now . . . Nathan [Carver] is helpful . . . but I am hampered by lack of tools . . . Also, it takes a long while to get back and forth to his place." Nonetheless, there was substantial news on the motor itself:

> I have changed the design somewhat. For one thing[,] the heads are clamped on with through bolts (as in the old [ARS No. 1] proving-stand motors) instead of using large-diameter threads—these proved very difficult to cut, and would have had to be done all over every time the motor liners & [cooling] jacket were enlarged or replaced. So the large-diameter threads were retained for the nozzle and oxygen inlet parts only; these were not so hard to cut. Also[,] the nozzle probably will be of chromium-plated copper, heavily lined on the exterior, rather than of Dural as originally planned. This idea was suggested by oxy-acetylene practice, where all the parts exposed to intense heat are of copper, water-cooled when necessary. The chromium plating is to resist the hot oxygen, of course. If it does not peel off, I think it will work very well. [25]

By 12 August 1937 he reported to Van Dresser that the motor was "beginning to look like something now, though I still have the nozzle and loxygen [*sic*] head to make. I have also ordered some sheet Monel from Whitehead for the fuel tanks." Following this, he characteristically plunged into exhaustive details on his overall rocket design—he really did intend to use the motor for the sounding rocket, but knew that if he could not "equal Goddard's stuff" he could do "more than anyone else has done."[26]

Back in January 1937, Wyld had obtained a job with the Process Development Department of Linde Air Products Co. in Newark, obtaining invaluable additional experience for his rocketry avocation as Linde was a major producer of LOX. At Linde, he did test work with oxy-acetylene shape-cutting machines and theoretical and mathematical studies on heat conduction, thermal stress, and combustion reactions at high temperatures. In this way, he was very qualified to give an ARS talk on 15 May "on the properties and handling of liquid oxygen, with special attention to production and use." Yet, due to "business turns," he was soon laid off in February 1938 and remained unemployed for sometime thereafter although was always heavily occupied with his rocketry. In the meantime, the January issue of *Astronautics* made another brief mention: "Many new experiments are being planned. Mr. James Wyld has completed a new regenerative motor."[27]

The Motor Tests

April 1938 opened up a most auspicious period for Wyld. He was named a Director of the ARS (at their meeting of the 29th) and Chairman of the Program Committee, and the Society's No. 2 Stand was nearing completion and would be ready in June. Apart from this, the April issue of *Astronautics* featured details of his motor written by him and accompanied by a labeled drawing.* Additionally, during April and May, his motor was already honored—before it had ever fired—when it was included with the "historic rocket motors" on exhibit at the New York Hayden Planetarium. The others were the "shot-scarred motors" of ARS rockets No. 2 and 4 and the complete ARS No. 3.[28] (Figure 5–3).

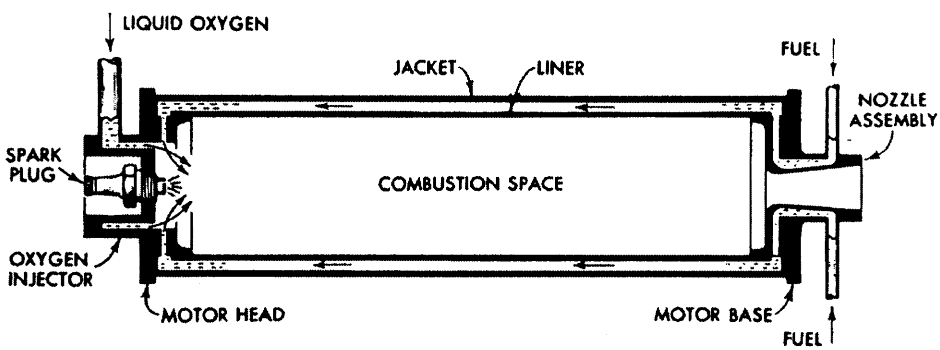

Figure 5–3: Drawing by Wyld, from *Astronautics* No. 40 of April 1938, of his regeneratively-cooled rocket motor which had actually evolved over several years from an initially complex design to this far-more simplified pattern. Smithsonian Photo A4560-E.

Wyld's April 1938 drawing shows a deceptively simple device. But as seen above and attested by his "Wyld 'M-15'" report, a great deal of ingenuity and solid engineering went into it. Following his description, as Wyld explained, "Care has been taken to insure [*sic*] rapid flow along the heated surfaces, thus improving heat absorption and avoiding the formation of vapor films. The multiple fuel and oxygen ports are expected to improve mixing. The fuel will be largely, if not entirely, vaporized in the chamber jacket, which ought to materi-

* Wyld never took out a patent on his invention, and his article helped establish his priority besides informing his ARS colleagues.

ally improve the combustion efficiency ... The completed motor will weigh only two pounds [0.91 kg] ... In view of the remarkable results claimed for similar designs by Dr. Sänger ... experimental tests should prove unusually interesting."[29]

However, there were "unavoidable delays in completing Proving Stand No. 2" and for another unknown reason, the Wyld motor was not tested during the first trials of the stand, made at New Rochelle, New York, on 22 October 1938, although Wyld was present. Rather, the tests occurred on 10 December when the stand was taken out for its second series of runs, also at New Rochelle. This was at a "better proving field," according to Wyld, within "an old abandoned house foundation on a vacant lot beside the house of Tucker Gugelman, a friend of the Westchester Rocket Society [a smaller, sister group of the ARS]..." Furthermore, the house was "... screened from the road by a hill, and ... in a sparsely settled neighbourhood; the old stone walls of the foundation made an admirable 'bomb proof shelter'..." "We have electricity at the proving field too," he added, "having run out a wire from the garage [of Gugelman]..." about 200 ft (60 m) away. But ARS Stand No. 2, which was slightly improved since the first New Rochelle tests, was not entirely portable. Weighing 300 lb, or 136 kg, it was not easy to handle and was hauled to the test site on a special two-wheel rubber-tired trailer made "from the front of an old Chevy truck" and pulled by a car to the site, although six men had to lift it onto the exact testing spot; the stand itself was provided with carrying handles. On testing day, which was dreary with drizzle hampering some of the operations, three motors were tried, the first with Hugh Franklin Pierce's tubular Monel motor. The second was a "tubular regenerative motor," made by Midshipman Robert C. Truax from the Naval College at Annapolis, Maryland.* The third motor tested was Wyld's.[30] (Figures 5–4 to 5–6).

Alcohol and LOX served as the propellants for all the motors. But instead of using the spark plug for ignition, because Wyld thought this might be too experimental for the motor, which was experimental in itself and not hot enough for ignition, he opted for a pyrotechnic fuse. "When ignited," read the report afterward submitted jointly by Shesta, Pierce, and Wyld, "a very large, diffuse, crackling, yellow flame was produced" in the Wyld motor, "but no reaction, showing that the combustion had failed to work back inside the motor from the fuse." However, Wyld's own account of the first run, written to Van Dresser the following day, goes into much more detail and also shows that although brief, it was much more successful than indicated in the report. "You can imagine," he began,

* Just how Truax arrived at his own regeneratively cooled motor and whether he was influenced by either Sänger or Wyld, or both, are unknown.

"how excited I was when we fired up—how excited everyone was, to see how this radical and much discussed motor would behave. On opening the valves, a long, crackling, diffuse yellow flame some eight feet [2.4 m] long shot from the nozzle and burnt for three or four seconds, when it suddenly shortened and burned for another two or three seconds with a short blue flame, marked by dark and light Mach waves at regular intervals. Then it went out. 'Water! Water!' shouted John [Shesta]," but the stand's water flushing system had broken down. Nonetheless, Wyld continued, "Amid the greatest excitement, we examined the motor [and] to our great delight, it had not only not burned out, but was perfectly untouched! Aside from a little sulphur and soot from the fusée on the outside of the muzzle [that is, nozzle], it was impossible to tell that the motor had fired, so perfectly clean and unscathed were all the parts." It was therefore decided, according to the report, "to give it a second trial," following a run with Truax's motor.* During the run of this motor, a side burned out and "only a small fragment remained." Thus, the fourth test this day was the Wyld motor again, this time using the remaining fuel of 3.5 lb (1.59 kg) of alcohol and 6.5 lb (2.95 kg) of LOX.[31]

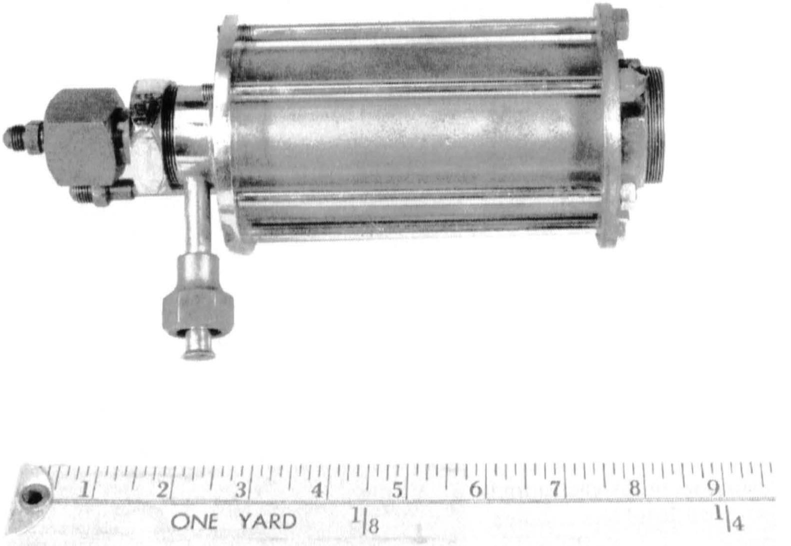

Figure 5–4: Specimen of one of the first Wyld motors, in the collections of the National Air and Space Museum, Washington, D.C., Wyld Serial No. 2, cataloged as Cat. # 1968-0226. Both Serial No. 1 and Serial No. 2 are almost identical. However, this motor lacks its fuel inlet line. See Endnote No. 40 for more on Serial No.'s 1 and 2. Scan, courtesy, National Air and Space Museum, Smithsonian Institution.

* Truax's motor also came with a jacket but was of larger and heavier and more conventional construction overall.

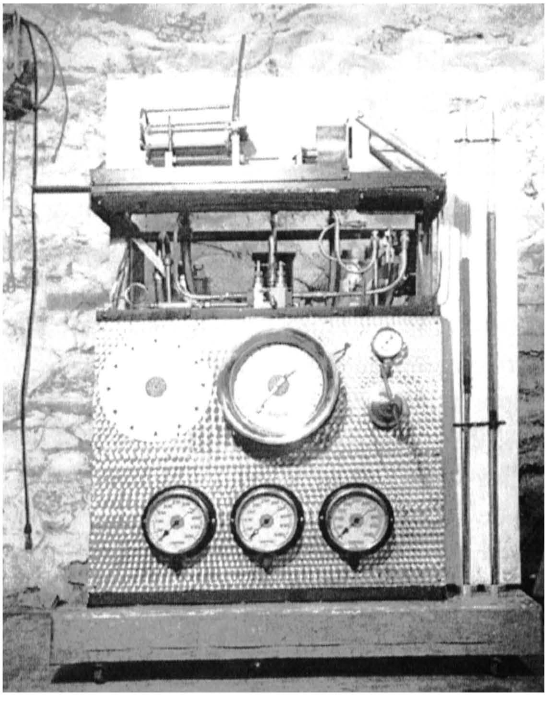

Figure 5–5: A rare view of the brand new American Rocket Society Test Stand No. 2, and Wyld's new regeneratively-cooled motor being "fit-checked" into the Stand, as seen on the top, photo taken by Wyld himself on 13 September 1938, a month before the Stand was first used. Another remarkable thing about this photo is that for many years the NASM had undeveloped negatives of pictures taken by Wyld and finally, about 2006—about 70 years after the photos had been taken—they were processed by the NASM's Photo Lab. They revealed this, and other stunning views of two artifacts presently in the Museum's rocketry collections, the Stand and the Wyld motor. Smithsonian Photo 9A05171.

Figure 5–6: James H. Wyld, left, besides ARS Test Stand No. 2, and other ARS members Joe Battaglia, middle, and John Shesta (back turned), at right, in preparation for the second series of tests with Stand No. 2, within an abandoned house foundation at New Rochelle, New York, on 10 Dec. 1938. This series was to include Wyld's motor—the first time it was ever tested—although the motor is not shown on the stand in this picture. Photo donated to the NASM by Wyld's sister, Mrs. Anne W. Blizzard, Washington, D.C. Smithsonian Photo 92-17120.

This time, for the ignition, "two large fusées were attached on opposite sides of the muzzle [nozzle], as well as some loose gunpowder inside the nozzle." "The run began," said the official report, "with a large yellow flame, which shortened into a straight, blue one after a few seconds, the reaction simultaneously rising to 90 pounds [40.82 kg], which was steadily maintained for about 13.5 seconds, after which it quickly fell to zero as the loxygen [*sic*] gave out. Examination showed that it was in good condition except for some melting and erosion of the head and liner about an inch from the injection ports." Wyld's own account, as described a day later in a 14-page letter to Van Dresser, is more dramatic: "At 3:30, as the grey afternoon was wearing on towards evening," he wrote, "we fired up [again], with anxiously beating hearts. And what a run that was! This time the motor caught instantly, and burnt with a clear, straight, sky blue flame about two feet [0.6 m] long, strongly marked with Mach bands. It burned and burned, with a roar fit to knock down the wall.... It seemed incredible that a thin aluminum wall could take such punishment. But at long last the flame suddenly died down, with a slight but ominous flash of white sparks. I vented the [water flushing] tanks and turned on the water, and we rushed to the stand in immense enthusiasm and excitement. The outside of the motor was perfectly sound, and the nozzle was intact, though coated with a thin film of metallic slag on the side..." The slag was later determined to be "not burnt Monel but a very thin film of aluminum." Wyld's letter to Van Dresser then went into finer details of the condition of the motor and the remainder of the testing that momentous day.[32]

The official report contains a graph analyzing the performance of the Wyld motor and attesting to its smooth performance; figures for the Pierce and Truax motors were not entirely possible because of their "rather erratic firing." The figures for the Wyld motor are: "(for the period of efficient combustion) Maximum reaction, 91 lb [41.28 kg]; alcohol feed, 0.084 lb/sec [0.038 kg/sec]; tank pressure, 250 lb/sq in. [18.61 kg/sq cm]; maximum exhaust velocity, 6,870 ft/sec [2,094 m/sec]; [and] maximum thermal efficiency, about 40%..." "These figures," concluded the report, "represent a great advance on those obtained in former tests, and are among the highest ever recorded. The fact that they were reached without severe damage to the motor is especially encouraging and definitely proves the feasibility of the regenerative method of cooling. The Experimental Committee is now preparing for another series of tests... Certain parts of the Wyld motor, originally of aluminum, are being replaced by Monel ones, to resist the heat better."[33] (Figure 5–7).

On Sunday, 11 December 1938, a day after the test, Wyld's letter to Van Dresser began on an ecstatic note: "It is rarely that I have any good news to send in these discouraging times [of the Depression], so I am writing a special letter... The good news is," he continued, "not that I have a job yet, but that my regenerative motor was tested for the first time yesterday, and proved a most striking and unequivocal success—the value of the principle [of regenerative cooling] is proven beyond any possible doubt." A couple of days later, on the 13th, he evidently wrote to Shesta, in which he agreed that "an extra long test of the motor was now called for," but this required funding, which he did not have although "considering the importance of the results of the last test, I believe somebody will certainly come across with a special contribution..."[34]

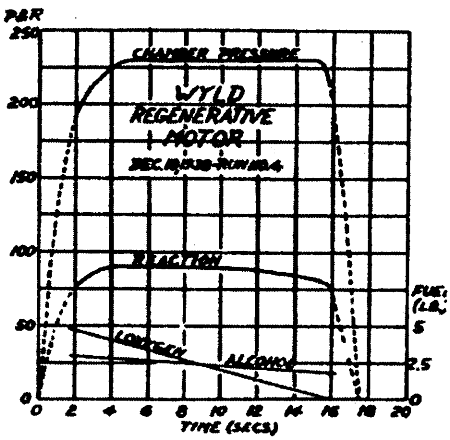

Figure 5–7: Graph made by the ARS's Experimental Committee of the run of Wyld's motor on 10 December 1938 (Run No. 4), showing an excellent and steady performance, with a maximum thrust of 91 lb (41.28 kg) and "without severe damage to the motor." It was still felt that more test firings were needed to be made to confirm the workability and efficiency of the motor. However, these later tests were not made until 1941. From *Astronautics*, No. 42, February 1939, p. 5.

He still entertained the use of the motor in a sounding rocket and expressed the same in his article "Experimental Rocket—Model 1939," appearing in the February 1939 issue of *Astronautics*. However, this plan still could not materialize because in the same issue, in "Notes and News," it was announced that he had resigned from the ARS Board of Directors (but not membership from the Society) "because of the acceptance of a position in another city." This job, which he only held from February to May 1939, was at the Griscom–Russell Co. at Massillon, Ohio, in which he was involved with test work on heat exchanger equipment and material specifications. Then, from 7 August to 19 June 1940, he worked for the National Advisory Committee for Aeronautics (NACA) at their Langley Research Center at Langley, Virginia. At the latter, he served as a Junior

Aeronautical Engineer and was in the 24-Inch High-Speed Wind Tunnel Group, under the famous aerodynamicist, John Stack. He worked on high-speed wind-tunnel development and tunnel flow analysis. He made his rocket avocation known though, as related in a letter of 24 February 1940 to Van Dresser, but he did not have tools available to him, nor a shop, and "Rocket work is in a difficult transition stage now—it is too big a job for the isolated experimenter and is considered too impractical to bother with by large research organizations like [the] N.A.C.A." In any event, despite his brilliance, he did not pass the Civil Service Commission Examination, which would have permitted permanent employment at Langley. Thus, apart from carrying on "a very voluminous correspondence with Shesta" and others "on rocket affairs" (mainly about building the elusive "big rocket,") little could be done to advance his progress on the motor.[35]

As matters developed, it was not until as late as 8 June 1941, two-and-a-half years after the first tests at New Rochelle, that Wyld was able to again test his vaunted motor. This was again on ARS Test Stand No. 2, at Midvale, New Jersey. A relatively new member was present, Lovell Lawrence Jr., an engineer with International Business Machines Corp. (IBM), who operated the ignition switch. The first motor to be tried was Wyld's, which had undergone minor changes, "mainly the substitution of an inner sleeve of higher melting point," but was otherwise the same. The propellants used were one gallon (3.8 liters) of alcohol and eight lb (3.6 kg) of liquid air, instead of LOX. The motor was ignited once more by an internal gunpowder fuse, and according to the report in *Astronautics* (August 1941): "The air in the valley vibrated, as did the spectators for these tests are exciting to witness. About the middle of the run there occurred a series of chugging sounds and fluctuations were visible in the exhaust flame. This seemed to have little effect on the thrust intensity, which hovered between 80 and 85 lb [36.3–38.6 kg] for the better part of the 26 second run." Again, it was a jubilant success. "Examination of the motor," concluded the report, "...revealed no damage to its internal parts. The outer sleeve was hot to the touch." The exhaust velocity was calculated as 5,000 ft/sec (1,524 m/sec), lesser than before but attributed to the use of liquid air rather than LOX. According to the official ARS "Observers" of the test, J. J. Pesqeira and Cedric Giles, the flame throughout the test slightly exceeded four ft (1.2 m) and had been "remarkably steady" through 80 percent of the run.[36]

On the afternoon of 1 August 1941, just a little more than two months following the prior test, the Wyld motor was subject to a series of yet three more tests, also held at Midvale. The report in the October issue of *Astronautics* was brief but conclusive. About 12 lb (5.4 kg) of propellants were used in the first test that "saw the motor fire for 21.5 seconds. The violet flame stretched out a distance of... three feet [0.9 m] from the nozzle. The deep roar was interspersed with sudden detonations spaced out about five seconds apart ["chugging"]. This phenomenon occurred in all three of the runs, but did no harm to the motor, though shaking the test stand and the cars." The second test, using about the same amount of propellants, ran for 23 seconds The last run, "with a leaner mixture than previously used, lasted for the surprising time of 45 seconds" while the thrust "at times reached 135 lb [61.2 kg]."[37] (Figures 5–8 and 5–9).

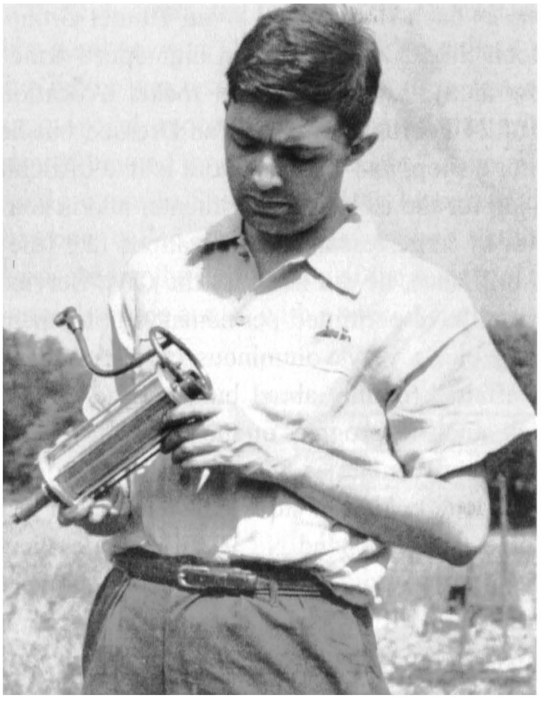

Figure 5–8: James Wyld with his motor at ARS static tests of 8 June 1941 at Midvale, New Jersey, with just minor changes made in the motor (the inner sleeve made of a higher melting point material). This time, alcohol and liquid air were the propellants. Again, the performance of the motor was another jubilant success with a post firing examination showing "no damage to its internal parts." Originally published in *Astronautics*, No. 41, August 1941, p. 3. Smithsonian Photo 83-2821.

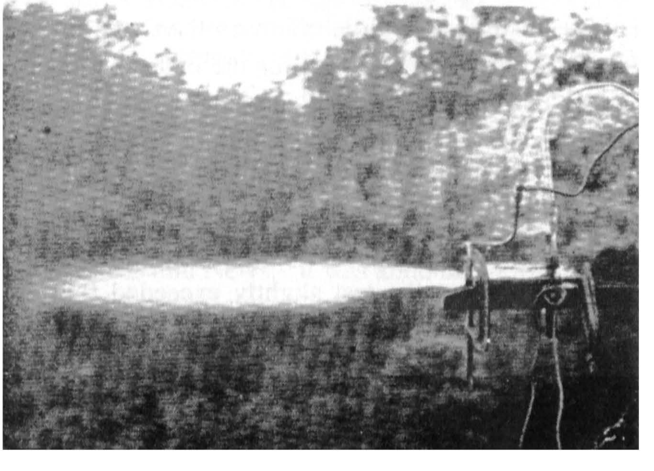

Figure 5–9: Firing of Wyld's regeneratively-cooled motor on 1 August 1941, also at Midvale, New Jersey. These final tests, reported Roy Healy in *Astronautics*, No. 50 for October 1941, "proved conclusively that a reliable motor for aerological sounding rockets has at least been designed, built, and tested." However, the U.S.'s entry into World War II on 7 December of that year completely changed the future applications of Wyld's revolutionary new motor. Original photo by ARS photographer W. Hecht and appearing in *Astronautics*, No. 50, given above, p. 8. Smithsonian Photo A4319B.

Formation of Reaction Motors, Inc.

It is very likely that if the United States had not entered World War II on the bombing of Pearl Harbor on 7 December 1941, the development of the little but highly successful Wyld motor would have languished. But events happened extremely quickly with the news of Pearl Harbor. However, even before this, with the war already raging in Europe and the threat that the United States might soon join in the conflict, Shesta, Pierce, Wyld—and now the business-minded Lawrence, all ARS members—started talking about the possibility of interesting the U.S. government in the motor for the war effort, should it come. Lawrence had even made arrangements for a Navy representative to witness a test run of the motor, and this is perhaps why, according to Bush, Navy Lt. C.[harles] F. Fischer, who then ran the one-man "rocket desk" of the Navy was among the spectators at the Midvale test on 1 August 1941. Bush also suggests that Wyld was induced to write his very comprehensive "Wyld's 'M-15'" report for eventual submission to the Navy.[38]

In any case, a little after a week following Pearl Harbor, on 18 December 1941, the four men formed Reaction Motors, Inc. (RMI), under the sponsorship of the Navy. Its first leased space, based in an old silver factory at Pompton Lakes, New Jersey, was 1,500 sq ft (139.35 sq m). This was the first U.S. (and probably the world's first) commercial company established for the development of liquid propellant rocket motors. Because Lawrence was the business-minded man among them with seven years experience supervising the installation of automatic radio-writing equipment for the government, working with IBM, he was made the President. Pierce was made Vice President, and Shesta the Treasurer. It was well recognized that Wyld, who had no inclination for business at all, was perfectly content to being named the Director of Research. However, the remainder of RMI's early history and many pioneering developments from here on has already been well documented in a series of previous IAF papers and articles by Winter and Ordway, III, besides an IAF memoir paper by Shesta. As mentioned at the outset, most notably these are RMI's development of JATOs and among the first U.S. missile motors, specifically the Lark and Gorgon missiles; the development of the famous 6000C-4 engine, also known as "Black Betsy," which powered the Bell X-1 that broke the sound barrier on 14 October 1947; and the engines for the Viking sounding rocket, the MX-774 test missile and precursor of the Atlas; and several other rocket research airplanes and projects.[39]

This chapter will, therefore, need only to briefly relate some salient points on Wyld's engine and on his later career. Shortly after RMI was formed, according to Shesta, they signed a contract with the Navy and were obligated to: (1)

deliver the existing Wyld motor to the Navy; (2) develop and demonstrate a similar 100-lb (45.36 kg) thrust motor, but operating on aviation gasoline and LOX; (3) develop a 1,000 lb (453.59 kg) thrust motor using the same propellants; and (4) demonstrate repeated starts and throttling of the engine down to half thrust. A replica of the original Wyld motor burned when tested with gasoline and therefore the problem was solved when the aluminum nozzle was substituted for a copper one. This motor subsequently passed the Navy's acceptance test although the first RMI models (up to June 1942, according to Wyld), "were very similar to the original design of 1938..."* Both the original and Navy versions became known as Serial No. 1 and 2 motors, respectively. Wyld relates how, under a series of small contracts, "numerous motors of rapidly increasing size were constructed" and the first models, up to June 1942, "were very similar to the original design of 1938." Interestingly, they were all test fired on ARS Test Stand No. 2 that was "borrowed" by RMI, although it was evidently slightly modified. Later, RMI built its own first "fixed" test stands. It is also important to point out that the RMI motor series start with the designation of M-16, and thus were *direct descendants* of his M-15. The motors were ideal for gaining experience and performance data for different mixture ratios and William C. House of Aerojet estimated that Serial No. 2 was run as many as 50 times from a few seconds to more than a minute in duration. By November 1942, RMI made successful runs of motors, using the basic Wyld principle, at over 1,000 lb (453.59 kg) thrust that was increased to 3,400 lb (1,542.21 kg) by May 1943. Meanwhile, both Serial No. 1 and 2 motors were relegated to a storeroom early in 1943, but in late 1945 or early 1946, this material, along with other early rocketry hardware, was packed at Annapolis and moved to the Pilotless Aircraft Unit, Naval Air Station, Mojave, California. Six months later the material was moved to the Navy Missile Test Center at Point Mugu, California. But in the summer of 1949, it was decided that a housecleaning was in order, and a large number of old rocket motors were loaded on a barge and dumped into the ocean off Point Mugu. Very fortunately, George W. Haughton, Jr., a former test mechanic who worked on the Wyld Serial No. 2 tests at Annapolis, was now stationed at Point Mugu and recognized the historical value of the Wyld Serial No. 2 engine and rescued it. Later, he gave it as a memento to William C. House of Aerojet who later became a Vice President of that firm and in May or June of 1967 donated it to the National Air and Space Museum.[40] † (Figures 5–10 to 5–12).

* The Navy version of the motor (Serial No. 2) is now in the collections of the National Air and Space Museum. See Endnote 40.

† A copy of the original M-15 motor was donated to the NASM in 1952 by the then Reaction Motors Division of the Thiokol Chemical Corp. Also see Endnote 40.

Figure 5–10: A week after the bombing of Pearl Harbor, Wyld and three other ARS members—Lovell Lawrence, Jr., John Shesta, and Hugh F. Pierce—formed Reaction Motors, Inc., in order to utilize the motor for the defense of the country. This photo, taken in the summer of 1942, shows several RMI members by the company's first truck, near RMI blockhouse at Franklin Lakes, New Jersey. Left to right, top: Franklin H. Pierce, John Shesta, and James H. Wyld; bottom, left to right: Joe Porter and Kurt F. Fischer. Photo taken by Robert Lawrence (brother of Lovell). Donated to the NASM by Kurt F. Fischer, May's Landing, New Jersey. Smithsonian Photo 89-5180.

As for Wyld, by 1943 he became Secretary of ARS, was a member of the Board of Directors in 1944, and in 1946 was elected President. An existing *Log Book* of RMI Motor Tests, covering the period from 20 March 1943 to 15 September 1944, in the collections of the NASM, shows that, from his unmistakable and always clear handwriting, he was very much involved with the day-to-day testing of the company's early motors. Except for periods of duty with the Atomic Energy Commission (AEC), he worked for RMI until the end of his life. By 1947, he became intently interested in the possibilities of atomic propulsion for rockets and served as a consultant to the AEC and was later on loan to them at their facilities at Oak Ridge, Tennessee.* Wyld was not overtly a promoter of

* A copy of a formerly secret memo, from 17 January 1947, that relates to RMI investigations begun on "the use of atomic power for jet-propulsion..." is in his NASM file.

spaceflight but was always enamored with the engineering challenges of the rocket itself. However, by 1952 he became a critic of Wernher von Braun's hugely elaborate concepts of a multi-engine space rocket as published in the famous *Collier's* series of articles. Instead, he called for a far less grandiose, more affordable "Model T" space ship. He extensively worked on this concept until his death, according to additional Wyld documents found in the archives of the U.S. Space and Rocket Center at Huntsville, Alabama. This included speaking with von Braun during his visit to RMI on 31 January 1953.[41]

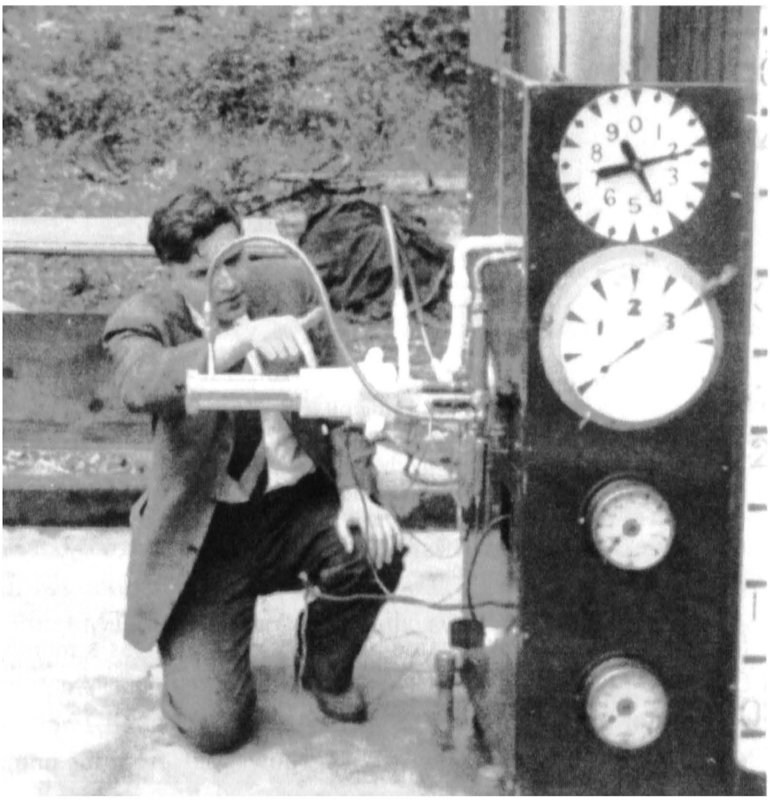

Figure 5–11: Wyld, after a static test of RMI motor M16-G on 20 September 1942, probably taken at their plant at Pompton Plains, New Jersey. Note the frost on the cooling jacket and "borrowed" elements from ARS Test Stand No. 2, including the clock and other dials. The M-16 designation mostly likely originated from Wyld's final version of his first successful regeneratively-cooled motor, the M-15, or "Motor 15." In other words, RMI's motors were successively improved variations of the original Wyld motor, and included sub-variations, and hence the M16-G model. Smithsonian Photo 78–18197.

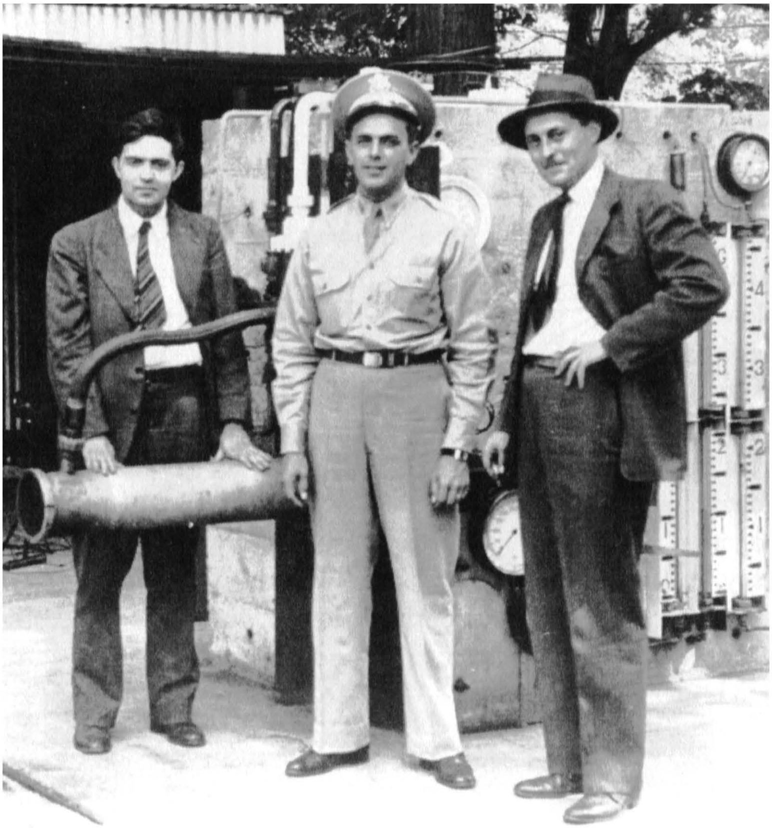

Figure 5–12: Wyld, at left, with an unidentified officer, and Lovell Lawrence, Jr., at right, with a vastly improved and more powerful 3,000 lb (1,360 kg) single-chambered RMI regeneratively-cooled motor, ca. 1944 or 1945. Note also, the greatly improved stationary test stand, although it still utilized elements, like the vertically-mounted glass propellant volume level gauges, at right, adopted from the original portable ARS Test Stand No. 2. Original ARS Test Stand No. 2 dials may have also been "borrowed." The Navy was always RMI's biggest war-time customer and these large motors were meant as critically-needed Jet-Assisted-Take-Off (JATO) units for heavily-loaded airplanes for operating from Pacific islands in the Pacific Theater. Photo, originally from the Frederick I. Ordway collection. Smithsonian Photo 89-1847.

This collection of Wyld documents also shows that toward the end of his career, he was heavily involved in helping to design the 50,000 lb (22,680 kg) thrust "Super-Viking" rocket engine, a precursor to the later RMI XLR-99 Pioneer rocket engine for the X-15 hypersonic research aircraft, and many other projects. The latter included further developmental work on the 6000C-4; helping design test stands for the 6000C-4; designing a "trajectory integrator" (1946), a kind of computer for rocket work; a proposed "Rocket Brake" for the American Locomotive Co. (1946) for slowing down trains; ramjet studies (1947); a Super

Bazooka (1948); "Long Range Rocket components" (1949–1952); work (in 1952) on the proposed LOX/Hydrogen Martin PT V-N-3 rocket; and others. Wyld only took out two patents in his lifetime, both with Lawrence. One was for a "Reaction Motor Control System," applied for on 15 November 1944 and granted on 17 May 1949 as U.S. Patent No. 2,479,564. The other was also for a "Controlling System for Reaction Motors," applied for 6 July 1943 and granted on 23 August 1949 as U.S. Patent No. 2,479,888. Wyld had married late in life. But he died at the tragically young age of 41 on 3 December 1953 at Pompton Lakes, New Jersey, then the location of RMI. Posthumously, in 1954, ARS established the James H. Wyld Memorial Award for those who made outstanding contributions to the application of rocket power. In 1975, this honor was renamed by the successor to ARS, the American Institute of Aeronautics and Astronautics (AIAA), as the Wyld Propulsion Award. He also became an inductee into the International Space Hall of Fame at the New Mexico Museum of Space History at Alamogordo, New Mexico, and the Aviation Hall of Fame and Museum of New Jersey, in Linden, New Jersey. (RMI was always located in New Jersey.) Finally, in 1970, he was posthumously bestowed with his most prestigious distinction, the naming of a crater on the far side of the Moon (Lat., 1.4°S, Long., 98.1° E.) in his honor.[42] (Figures 5–13 to 5–16).

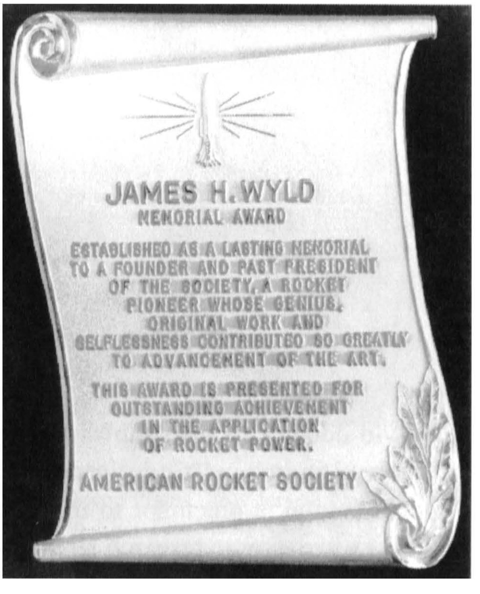

Figure 5–13: James H. Wyld Memorial Award established in 1954 by the American Rocket Society. Later, the ARS became the American Institute of Aeronautics and Astronautics (AIAA) and in 1975 the honor was renamed the Wyld Propulsion Award and is still conferred annually to an individual who makes the most significant achievement in propulsion in that year. Photo, originally from the American Rocket Society. Smithsonian Photo 82-5370.

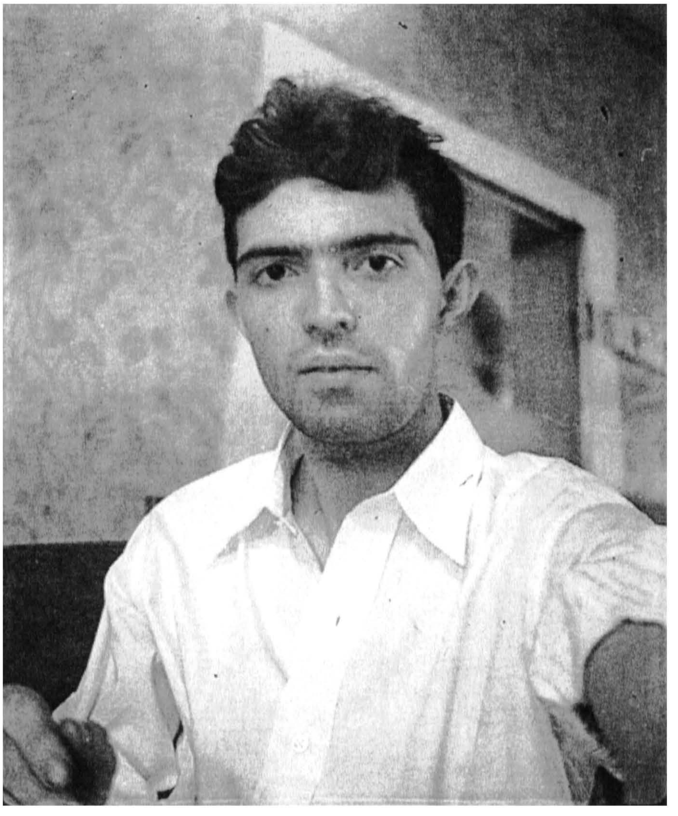

Figure 5–14: Another rare photo, a self-portrait of Wyld, taken at Elmira, New York, July 1937, probably at the time of the Eighth Annual National Soaring Contest held at Elmira during 26 June to 11 July 1937. Wyld was a man of varied interests, including aviation and other pictures in this series depict planes at the event. This, almost haunting portrait, was another one of the pictures discovered when the Wyld negatives were finally processed about 2006, or almost 70 years after the pictures had been taken. This is the first time this picture has been published. Smithsonian Photo 9A05236.

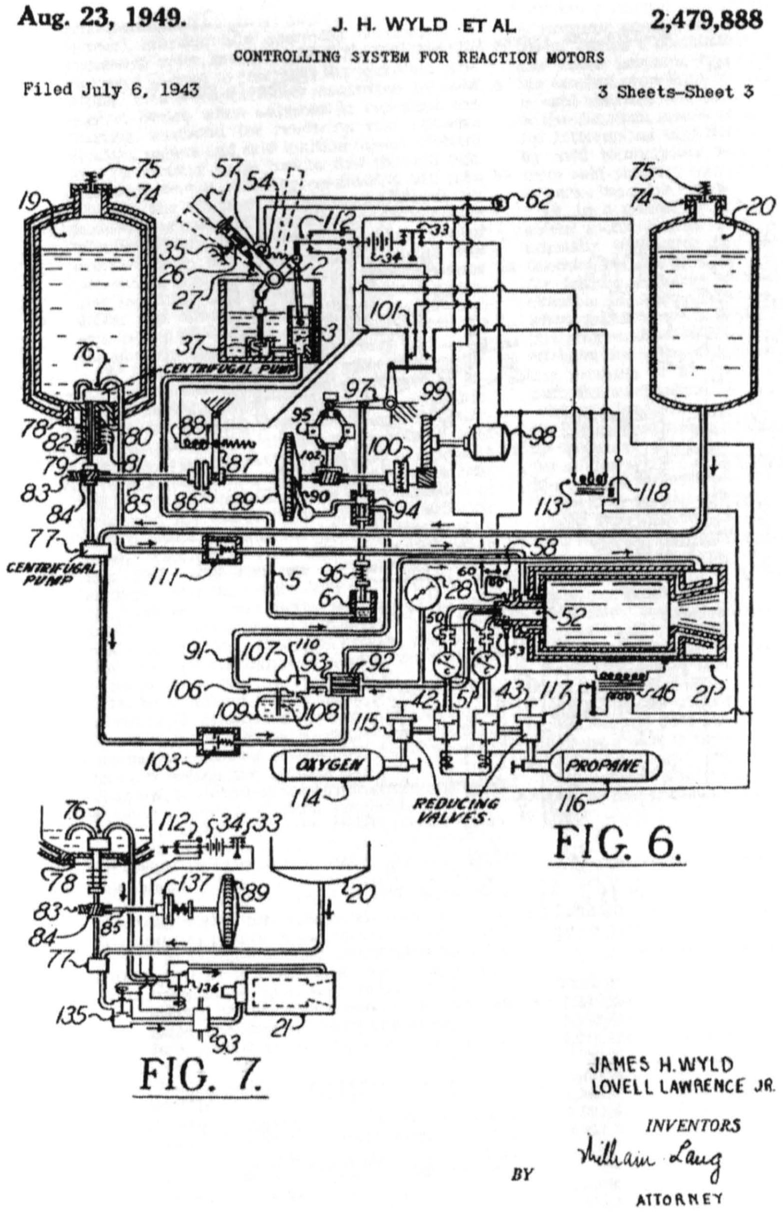

Figure 5–15: One of two patents taken out by Wyld during his life-time, filed on 8 July 1943 with Lovell Lawrence, Jr., and granted on 23 August 1949 as U.S. Patent No. 2,479,888 for a "Controlling System for Reaction Motors." Wyld never took out any patents for his regeneratively-cooled rocket motor simply because he wished to "share" this idea with others. Moreover, his development, building, and repeatedly successfully testing the engine were well established in the ARS journal and elsewhere. U.S. Patent No. 2,479,888.

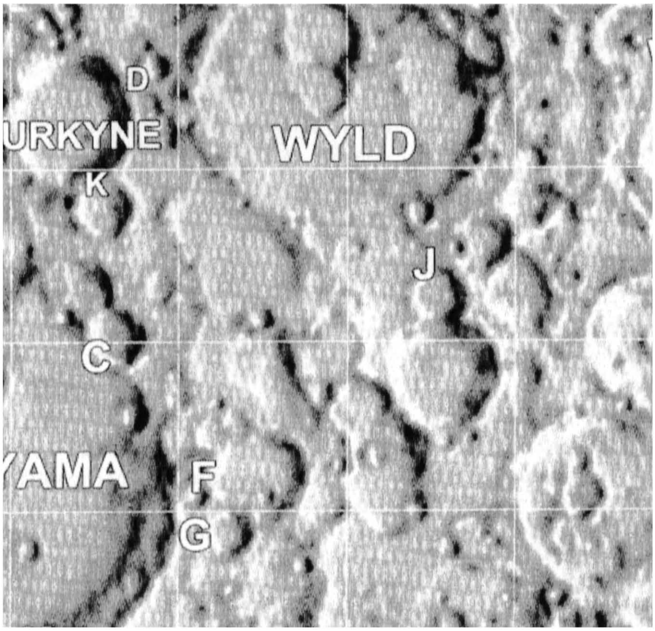

Figure 5–16: Although he could never have imagined it, Wyld received his highest honor in 1970 for his achievements when a 93 km (57.8 mile) diameter crater on the far side of the Moon was named in his honor (Lat. 1.4° S., Long. 98.1° E.). Courtesy, Dr. James R. Zimbelman, Center for Earth and Planetary Studies, National Air and Space Museum.

Endnotes

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2 Winter, "Bringing Up Betsy"; Wyld, "James Hart Wyld"; letter, Dwight C. Baum to Frank Winter, 15 December 1988, copy in "James H. Wyld" file, NASM.

3 James H. Wyld, *Diary*, in collections of the NASM, Accession No. 2005-0051, n. p. [pp. 36–37, end of entry for 6 April 1936?]; James Wyld, "The Prehistoric Era of the Regenerative Motor," *The Rocket* (Reaction Motors, Inc., December 1951), p. 5; Andres, Ugo [G. Edward Pendray], "Men of Space," *New Outlook* (New York) Vol. 164, (October 1934): pp. 26–33; Frank H. Winter, *Prelude to the Space Age—The Rocket Societies: 1924–1940* (Washington, DC: Smithsonian Institution Press, 1983), pp. 82, 121; letter, Baum to Winter.

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[5] Winter, *Prelude*, p. 83.

[6] Winter, "Bringing Up Betsy," p. 79.

[7] Wyld, *Diary*, n. p. [p. 39]; Bush, pp. 12–13.

[8] Letter, James H. Wyld to G. Edward Pendray, 27 April 1935, in Peter Van Dresser Collection, NASM.

[9] Letter, Wyld to Pendray, 27 April 1935, with mention of Bull on page 16; Peter van Dresser, "The Rocket Motor—A Survey of Known Types," *Astronautics*, No. 33 (March 1936): p. 10.

[10] Letter, James H. Wyld to G. Edward Pendray, 19 June 1935, in Peter Van Dresser Collection, NASM.

[11] Wyld, "The Prehistoric Era."

[12] Irene Sänger-Bredt and Rolf Engel, "The Development of Regeneratively-Cooled Liquid Rocket Engines in Austria and Germany, 1925–42," in Frederick C. Durant III and George S. James, editors, *First Steps toward Space—Proceedings of the First and Second History Symposia of the International Academy of Astronautics at Belgrade, Yugoslavia, 26 September 1967, and New York, U.S.A., 16 October 1968* (Washington, DC: Smithsonian Institution Press, 1974), p. 219 [republished as *First Steps Toward Space* (San Diego, California: Published for the American Astronautical Society by Univelt, Inc., 1986), AAS History Series, Vol. 6].

[13] Sänger-Bredt and Engel, pp. 220, 245; Letter, Esther C. Goddard to Dr. Eugene M. Emme, 27 March 1965, copy in "Robert H. Goddard" file, NASM.

[14] George P. Sutton, *History of Liquid Propellant Rocket Engines* (Reston, Virginia: American Institute of Aeronautics and Astronautics, 2006), pp. 79, 245, 283.

[15] Letter, Mrs. Esther C. Goddard to [Dr.] Eugene E. Emme, 3 April 1965, copy in "Robert H. Goddard" file, NASM.

[16] Letter, Goddard to Emme, 3 April 1965. A picture of this motor can be found as Fig. 32 in Esther C. Goddard and G. Edward Pendray, editors, *The Papers of Robert H. Goddard* (New York: McGraw-Hill, 1970), Volume 1, p. 507.

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[21] Letter, partial only, p. 8, James H. Wyld to unknown recipient, 28 January 1936, in "James H. Wyld" file, NASM; Bush, pp. 12, 22.

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[26] Letter, James Wyld to Peter Van Dresser, 12 August 1937, NASM.

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[31] Shesta, Pierce, and Wyld, "Report on the 1938 Rocket Motor Tests," p. 5; letter, Wyld to Van Dresser, 11 December 1938.

[32] Shesta, Pierce, and Wyld, "Report on the 1938 Rocket Motor Tests," p. 5; letter, Wyld to Van Dresser, 11 December 1938.

[33] Shesta, Pierce, and Wyld, "Report on the 1938 Rocket Motor Tests," pp. 6–7; letter, Wyld to Van Dresser, 11 December 1938.

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[40] Shesta, "Reaction Motors"; Wyld, "The Liquid-Propellant," p. 9; Letter, W. C. House to Fred[erick] C. Durant, III, 9 June 1967, copy in "James Wyld" file, NASM. Wyld motor, Serial No. 1, is catalogued as Cat. # 1952-0057 in the National Air and Space Museum. Serial No. 2 is Cat. # 1968-0226. In addition, there is a spare nozzle for the Wyld for Serial No. 1, as Cat. # 2001-0658. However, it was recently learned that the original Wyld Serial No. 1 motor apparently no longer exists. A careful re-examination of the NASM artifact and record of what was previously believed to have been the Wyld Serial No. 1 reveals that it has the name "Reaction Motors, Inc." followed by the designation number "M15G1-1" stamped around the periphery of an internal retainer ring of the motor and not seen on the motor as presently exhibited. These clues, plus a letter in the artifact (Registrar's) file on this object, from Lovell Lawrence, Jr. to Dr. Frank A. Taylor, a Curator of the National Museum (of the Smithsonian Institution), dated 27 September 1948, says it is: "The first model of the gasoline motor developed under that [Navy] contract [to RMI] and is practically an exact duplicate with the exception of the materials of contruction." In other words, this is an RMI-made variant of the Wyld Serial No. 1 motor which, according to the same letter, "was turned over to the [Navy's] Bureau of Aeronautics as part of our [RMI's] first contract." Moreover, the RMI designation "M15G1-1" probably means "[Wyld Motor 15, Gasoline Model, 1-1] [first in a series]." This motor was in actuality the RMI *prototype* of the Wyld Serial No. 2 motor (i.e. it was never turned over to the Navy as an "operational" Serial No. 2). As for the "Serial No. 2" motor in the NASM's collections (Cat. # 1968-0226), a letter in the respective file from William C. House of Aerojet to Frederick C. Durant III of the National Air and Space Museum and dated 9 July 1967, makes it very clear that this is operational Serial No. 2 and, as mentioned, that it may have been fired as many as 50 times, including mixture ratio and other tests by the Navy at Annapolis, Maryland. The fact that it

is missing its fuel inlet line seems to confirm this heavy usage of it. It thus appears that this was probably the second and *final* Serial No. 2 type motor[s] produced by RMI. In short, RMI's development of Serial No. 2 to fulfill their first Navy contract was more complicated than first appears.

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