NASA Technical Memorandum 100232

A Life Test of a 22-Newton (5-lbf) Hydrazine Rocket

(NASA-TM-100232) A LIFE TEST OF A 22-NEWTON (5-lbf) HYDRAZINE ROCKET (NASA) 12 p N88-11750
Avail: NTIS HC A03/MF A01 CSCL 21H
Unclas
G3/20 0107554

P.R. Meng, S.J. Schneider, C.J. Morgan,
and R.E. Jones
Lewis Research Center
Cleveland, Ohio

and

D.A. Pahl
Rocket Research Company
Redmond, Washington

Prepared for the
1987 JANNAF Propulsion Conference
San Diego, California, December 15-17, 1987

NASA

A LIFE TEST OF A 22-NEWTON (5-LBF) HYDRAZINE ROCKET

P.R. Meng, S.J. Schneider, C.J. Morgan, and R.E. Jones
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

and

D.A. Pahl
Rocket Research Company
Redmond, Washington

E-3857

ABSTRACT

Life tests were conducted on a 22-N (5-lb) hydrazine rocket thruster which incorporates the latest technology to obtain long life from the catalyst bed. A spring mechanism surrounding the catalyst bed continually applies compression to the catalyst bed to prevent the formation of any void channels. The thruster was instrumented and then installed in a high altitude facility at the NASA Lewis Rocket Engine Test Facility. The Rocket Research thruster was tested over an operational cycle of both steady-state and pulse firing which simulated a possible Space Station duty cycle. The thruster ran as expected for about 40 hr, or $3.2x10^6$ N-sec ($7.2x10^5$ lb-sec) total impulse. Subsequently, some thrust chamber pressure decreases were noted during long steady-state test periods.

After 60.2 hr of run time, the tests had to be terminated due to a blockage in the propellant injector tube which occurred during heating of the thruster by a heat lamp. The thruster had accrued over $4.8x10^6$ N-sec ($1.1x10^6$ lb-sec) of total impulse before the injector tube was inadvertently blocked. After disassembly and inspection of the thruster, a chemical analysis of the catalyst indicated that iron and nickel metals had poisoned some of the catalyst, thereby, causing a degradation in performance. It was determined that a contaminated or "pink" barrel of hydrazine was the source of the metal poisoning. An examination of the catalyst bed compression spring indicated that approximately 2 percent life remained. It is possible that the use of contaminated hydrazine may have caused the catalyst loss rate to accelerate and the thruster life may be greater than reported in this paper.

INTRODUCTION

Hydrazine thrusters have been successfully utilized for various shuttle and satellite missions for a number of years. These thrusters have a limited life because of voids which ultimately occur due to catalyst loss. The voids in the catalyst bed cause the thruster operation to become rough. This roughness, as measured by chamber pressure peak to peak oscillations, is the criterion which usually determines the "end of life" of the thruster. The value of acceptable roughness is predetermined by the type of mission for which the thruster is used, and normally varies between 15 and 50 percent. Another potential thruster failure mode is poisoning of the catalyst, which occurs when a foreign substance comes in contact with the catalyst bed. These contaminants are deposited on the active catalyst surfaces, thereby reducing the effective area for decomposition. The reduced activity in the catalyst causes the flame front to shift, which ultimately results in a drop in chamber pressure and degradation of the thruster performance due to incomplete decomposition of the hydrazine. This phenomenon is called "washout" and, in severe cases, causes the engine to shutdown. Many variables such as; duty cycle, chamber pressure, shape and loading of the catalyst bed, type of containment, etc. are involved in this phenomenon and are covered in detail in the Refs. 1 and 2.

Future applications such as space station platforms will require long-life thrusters which will be used for both short pulses and long steady-state firing. Rocket Research Company developed and tested a long-life 22-N (5-lbf) hydrazine thruster under an Advanced Development Contract from the Air Force (Ref. 3). The thruster was designed, fabricated and tested to demonstrate its capability to meet the demanding mission requirements of future military satellites. In previous tests conducted by Rocket Research Company, (RRC), under an Air Force contract, a similar thruster was tested to $3.6x10^6$ N-sec (806, 770 lb-sec) total impulse, and a second was fired for 528 000 pulses. In other tests at the Air Force Rocket Propulsion Laboratory (Ref. 4), AFRPL a similar hydrazine thruster was fired for 1 020 000 pulses. These tests were conducted simultaneously on five different thrusters over a range of short pulses varying between 25 to 2000 msec. The RRC Thruster used in these tests was the same design as the one used in the NASA tests with a compression spring surrounding the catalyst. The RRC thruster did experience roughness and performance degradation during these tests. As determined later in the disassembly and inspection at Rocket Research Company (Ref. 5), these problems were caused by a leaking propellant valve and high valve temperature due to inadvertent operation of external heat lamps. The roughness problem encountered in these tests is an artifact of firing with the thruster pointed vertically down in a 1-g field. Horizontal firing more closely approximates the 0-g condition for which the compression spring is designed. In a vertical attitude, the catalyst tends to settle and packs in an axial orientation which is a configuration for which it is difficult for the spring to eliminate the voids.

In an effort to provide needed monopropellant hydrazine thruster technology for future NASA missions, a Technical Exchange Agreement (TEA) was reached between Rocket Research Company and NASA. Under the TEA, a new RRC thruster would be tested at NASA Lewis Research Center until an "end of life" failure occurred. The criterion for thruster "end-of-life" for these tests was predetermined to be a chamber pressure fluctuation or roughness of 15 to 20 percent.

ENGINE DESCRIPTION

Rocket Research Company developed the Radial Outflow/Dynamic Retention Engine (Fig. 1) under an advanced development contract (Ref. 3). The unique feature of this engine is its catalyst bed dynamic retention system. The radial flow bed is contained by a radial bed-plate which is acted upon by a compression band. The compression band is anchored to the thrust chamber at one end and to a torsional spring at the other. The spring applies a compressive force on the catalyst bed and collapses any void that may develop during operation.

The propellant injector tube runs through the center of the radial flow bed. Hydrazine enters the catalyst bed through three longitudinal slots in the tube and is dispersed by a Poroloy Nichrome V dispersion element. The radial catalyst bed uses 20.92 g of Shell 405, 25 to 30 mesh catalyst, and has a 0.53-cm (0.21-in.) inner diameter, a 2.87-cm (1.13-in.) outer diameter, and a 2.28-cm (0.9-in.) axial length.

The thrust chamber is made of Hastelloy B, 6.02-cm (2.37-in.) in diameter with a 40:1 bell nozzle. The propellant valve is a single-coil, single-seat valve. A photograph of the thruster with some instrumentation is shown in Fig. 2.

INSTRUMENTATION

Chromel alumel thermocouples were used to measure temperatures at the thruster throat, chamber wall, injector tube, and inside the thrust chamber body. Two chamber pressure taps as shown in Fig. 2 were located in the thrust chamber body. These chamber pressure measurements were averaged and used to monitor thruster roughness. As the catalyst is depleted to the point where voids are formed in the bed, thruster operation becomes rougher. The percent roughness is calculated from the chamber pressure measurements with a predetermined value of 15 to 20 percent roughness considered as the "end of life." Hydrazine flow rates were measured by averaging readings from two turbine flow meters. Thrust was measured by load cells and calculated using the average of the two chamber pressure (Pc) measurements. The measured thrust utilized three load cells which were previously used for a much larger engine; therefore, the measured thrust was not very accurate. Since the tests were for "end of life", the thrust calculated from the chamber pressure measurements was adequate and appeared to be consistent with previous thruster test data (Ref. 3).

FACILITY DESCRIPTION

Testing was accomplished in an altitude test stand at the Rocket Engine Test Facility (RETF) at NASA Lewis. This facility is normally used for testing large rocket engines with thrust levels ranging up to 4.4×10^3 N (1000 lb) at nozzle area ratios as high as 1000:1 and background pressures as low as 2.07 KPa (0.03 psia). A smaller test facility was not available at the time; therefore, in order to expedite the hydrazine thruster tests, this large facility was utilized. A cutaway illustration of the RETF facility is shown in Fig. 3(a) with a schematic of the facility shown in Fig. 3(b). The test capsule was constructed in two parts; one part was the fixed bulkhead on which the thruster was mounted and the other part was the retractable tank which can be rolled back to provide access to the hardware.

For the hydrazine tests, the test thruster was mounted horizontally in the test capsule with the thruster exhausting into the small diffuser shown in Fig. 4. The small diffuser was water-cooled and exhaust gases were pumped from this small diffuser into the larger diffuser shown in Fig. 3. The exhaust then passed through the spray cooler, and then to the ejectors which exhausted vertically to atmosphere. The ejector system provided an ignition-free, pumping action necessary with the hydrogen filled environment produced by the thruster. The ejector system used for these tests utilized service air with unlimited supply at its designed flow.

During the test of the thruster, the kinetic energy of the thruster exhaust gases acted with the diffuser to evacuate the test capsule environment to a lower pressure 0.69 KPa (0.1 psia) than that provided by the service air ejectors alone 2.07 KPa (0.3 psia). The two ejectors were used in series providing a two-stage pumping arrangement.

The thruster was mounted on a thrust stand attached to the fixed end of the test capsule as shown in Fig. 4. In this figure, the movable part of the test capsule has been rolled away on its track toward the spray cooler. The diffuser is still in place in the figure, but can also be rolled away to provide access to work on the hardware. Figure 4 shows the mounting plate of the thrust stand on the right side. The thruster is at the center of the figure with the propellant line entering the thruster from the right. The thruster control valve is mounted to the thruster. The bleed line shown in Fig. 4 is used to eliminate nitrogen vapor when initially filling the propellant line with hydrazine. Dead end piping to pressure transducers and thermocouples was placed in a downward position to avoid vapor being trapped in the system. Behind the thruster is a heat lamp used to precondition the catalyst bed temperature to approximately 121 °C (250 °F) prior to each cold start. This heat lamp was used in lieu of a catalyst bed heater which would be used in a flight design. Shown at the top of Fig. 4 are the two transducers used to measure chamber pressure.

TEST PROCEDURE

The thruster was tested over an operational cycle of both steady-state and pulse firings which could possibly simulate a space station duty cycle. A typical test would start with the service air ejectors evacuating the test capsule and spray cooler to a pressure of approximately 2.07 KPa (0.3 psia). Then the propellant run tank would be pressurized to a pressure corresponding to the desired flow condition. The heat lamp would be used to heat the thruster (and catalyst) to a 121 °C (250 °F) temperature. Coolant water flow was then started through the small diffuser. The thruster was then fired by opening the thruster control valve to flow hydrazine over the catalyst. During the test firing, the exhaust gases entrained the remaining gases in the test capsule and carried them out through the diffuser. This pumping action decreased the test capsule pressure to 0.69 KPa (0.1 psia).

Certain parameters were monitored during the test to abort the test automatically if any of the following parameters were "out of range": chamber pressure, hydrazine flowrate, test capsule pressure, ejector supply pressure, or diffuser cooling water pressure. No attempt was made to control the temperature of the hydrazine delivered to the thruster.

At shutdown of the thruster, the pressure differential across the diffuser created by the thruster pumping action would result in a pressure pulse from the spray cooler back to the test capsule, raising the test capsule pressure back to 2.07 KPa (0.3 psia). The ejectors continued to evacuate the system while the thruster was allowed to cool to 482 °C (900 °F) (duty cycle temperature if in a cycling mode) or to 93 °C (200 °F) if testing for the day was completed. In the latter case, the isolation valve between the ejectors and the spray cooler was closed and then the ejectors turned off. Nitrogen was then bled into the test capsule to slowly raise the capsule pressure back to atmospheric pressure. These precautions were taken to prevent the hot catalyst (above 121 °C (250 °F)) from damage which could be caused by oxygen in the test capsule. Even with these precautions, during one test, fire flashes were seen inside the test capsule via television monitors. These flashes of fire were caused by a small air leak at the main "O" ring which seals the fixed bulkhead and the retractable tank. The air leak was repaired and no flashes were seen during the remainder of the tests. However, there was concern that the oxygen from this air leak may have poisoned the catalyst since it was at operational temperatures when this leak occurred.

Hydrazine was left in the system at the end of a test. When the thruster was to be removed from the system, helium was used to purge the lines of hydrazine. Then the helium was used to purge any remaining hydrazine through the thruster (with thruster temperature between 121 °C (250 °F)) and 204 °C (400 °F)). Helium was selected for the purge gas when the gaseous nitrogen analysis revealed traces of water and oxygen in the available nitrogen supply. If the thruster were to be removed, the helium purge was continued for one hour and the thruster heated with the heat lamp to 88 °C (190 °F) under a vacuum for 2 to 3 hr to decontaminate the thruster.

TEST RESULTS

The planned test firings for the life test of the thruster are shown in Table I. The long firing times might be typical of times such as orbit raising or collision avoidance maneuvers. The shorter firing times are more typical of attitude control operations. Table I also shows the actual test times obtained with the thruster (not in chronological order) as well as the level of total-impulse achieved.

In actual operation the chamber pressure fluctuations were on the order of 6 to 7 percent and never reached the 15 to 20 percent level which was the criterion for end-of-life. After approximately 3.5×10^6 N-sec (7.5×10^5 lbf-sec) of total impulse was obtained, a drop-off in chamber pressure began to occur with increasing frequency. Figure 5 shows a typical trace of chamber pressure where this drop-off was observed. On occasion, this drop-off in chamber pressure would be great enough to trigger an automatic shut-down. However, as this figure illustrates, sometimes the pressure would recover and the test proceed as before. This phenomena is well documented in the hydrazine thruster literature and is known as "washout" (Refs. 1 and 2). This washout was thought to be caused by the gradual accumulation of aniline in the catalyst bed. The hydrazine used in this program was "propellant grade" and contained about 0.337 percent aniline as shown in the chemical analysis in Table II.

During the extended test firings, aniline could gradually build up and contaminate a portion of the catalyst bed. Eventually, hydrazine would pass through a portion of the catalyst bed without contacting any active catalyst. This results in a drop in chamber pressure as all the hydrazine is not being decomposed. A reduction in chamber pressure (and a corresponding increase in fuel flow) results in a change in the gas flow pattern through the bed, which could now bring hydrazine into contact with active catalyst resulting in a restoration of the chamber pressure to previous levels. Such an occurrence is illustrated in Fig. 5. This problem would not occur if the thruster was used in a space flight application because the aniline would rapidly outgas after each firing. However for these tests, the test capsule pressure was high enough that the outgassing of the aniline was not completed between test firings.

An attempt was made to bake off the potential aniline contamination of the catalyst by heating the thruster with the heat lamp while the test capsule was under vacuum. Unfortunately, the propellant valve was also subjected to the heating causing the residual hydrazine trapped in the valve to decompose. This autodecomposition resulted in internal pressures in the valve which caused it to violently explode. The propellant valve was replaced, but the thruster would not ignite. The test was terminated at this time because the fuel feed tube in the thruster was plugged. All attempts to reopen the tube were not successful and all remedies suggested seemed likely to impact the validity of further life testing.

POST-TEST DISASSEMBLY AND ANALYSIS

The thruster was removed from the test chamber after the attempt to bake off the catalyst bed contaminants with a heat lamp resulted in the autodecomposition of the hydrazine fuel entrapped in the valve. When the valve exploded violently, part of the Teflon valve seat was forcibly ejected into the thruster's fuel injector, causing it to become plugged. Attempts at removing the plug failed, so the thruster was returned to Rocket Research Company for disassembly and analysis.

The aft thruster chamber (and attached heat shield) was cut open and separated from the rest of the thruster. Visible accumulations of catalyst fines were present on all internal surfaces, Fig. 6. The torsional catalyst bed compression spring was taken up to 98 to 100 percent of its maximum deflection with the spring travel almost at the stop as indicated in Fig. 7. All internal moving parts moved smoothly through their full range of motion, and all internal metal parts showed no mechanical or thermal degradation under close examination.

The bed retainer nut, lubricated before testing began with magnesium oxide and tack-welded into place, was easily removed after the weld was machined off. The aft bed closure and bed support were removed, exposing the catalyst bed. The catalyst, Fig. 7, completely filled the catalyst bed chamber with no apparent voids or visible particle degradation. Some catalyst particle penetrations through the bedplate slots were apparent. The outer 53 percent (by distance from the injector) of the catalyst particles visible, appeared gray and "dusty," while the inner 47 percent appeared smooth and shiny. The catalyst was "cored" concentrically with the injector using a modified 5 cc laboratory syringe. The inner bed sample weighed 5.3 g (31 percent of total weight) and was collected from the injector surface out to a 0.59-cm (0.233-in.) radius. The outer bed sample weighed 11.63 g (69 percent of total weight) and was collected from the catalyst bedplate to a 0.60-cm (0.235-in.) radius from the injector centerline.

Before testing began, 20.92 g of 25 to 30 mesh catalyst were loaded into the thruster. 3.99 g of catalyst (19.07 percent of total weight) were lost as fines during testing. The thruster was designed to allow up to a 20 percent catalyst loss without developing voids in the catalyst bed. A particle size analysis, Table III, showed no significant change in particle size distribution between the outer bed and inner bed samples taken.

In an effort to determine what caused the "washout" during the tests, oxygen poisoning and hydrogen chemisorption tests were run on the two catalyst samples. The oxygen poisoning tests showed a 9.5 percent oxidation in the outer bed and a 6.6 percent oxidation in the inner bed. These values are within acceptable limits for normal thruster operation, and do not indicate that the air leak in the test vacuum chamber into the hot catalyst bed caused a significant problem leading to the earlier thruster "washouts." The hydrogen chemisorption tests showed 77 μmol of hydrogen absorbed onto each gram of dry catalyst in the outer bed and 49 μmol on the inner bed samples. The outer bed was more chemically reactive than the inner bed. These values are considered abnormally low and not typical for a catalyst with the amount of run time accrued on the thruster. Chemisorption values this low would be expected to lead to incomplete decomposition of the hydrazine.

In order to determine the cause of the "washout," a metals analysis was conducted by digesting the catalyst bed samples in acid and analyzing the dissolved metals. The results, Table IV, showed an abnormally high concentration of iron and nickel which probably lead to the low hydrogen chemisorption values. The highest metals concentrations came from the inner bed sample. This is consistent with metals dissolved into the fuel from tankage and transfer lines entering the catalyst bed and being deposited onto the catalyst particles. It was determined from a chemical analysis of the hydrazine in the run tank, after the testing was completed, that one barrel of "pink" hydrazine had been mixed with the hydrazine in the run tank and was used during the tests. Pink hydrazine results from air leaking into an improperly sealed drum. The air results in a chemical reaction between the hydrazine and carbon dioxide forming water, and carbazic acid. The corrosive carbazic acid ($H_2NNHCOOH$) reacts with the metal drum and as iron is leached out it contaminates the hydrazine. The iron will then cause poisoning of the catalyst, resulting in a "washout" condition during testing.

Further inspection of the thruster injector by a water flow calibration showed that the flow through the injector was almost completely cut off by the Teflon from the valve seat. A pre-test flow calibration at 276 KPa (40 psia) flowed 856.4 g/min, while a post-test calibration flowed only 7 g/min of water. Post-test photographs of the exposed injector, Fig. 8, clearly show why the post-test injector flow rate was so low. Teflon from the ejected valve seat was extruded through the small injector orifices and was forced into the fuel delivery slots behind the injector dispersion element.

CONCLUDING REMARKS

A 22-N (5-lbf) spring loaded hydrazine rocket thruster was tested to "end of life" under a Technical Exchange Agreement with the Rocket Research Company. The thruster was operated in a vacuum test facility at the NASA Lewis at conditions simulating both the steady-state and pulse firing requirements which may be needed by the space station or other missions for drag makeup and orbital maneuvering.

The thruster ran as expected for 40 hr, delivering 3.2×10^6 N-sec (7.2×10^5 lb-sec) of total impulse. Subsequently, some chamber pressure oscillations were noted during long steady state testing. However, these chamber pressure oscillations never reached the predetermined "end of life" roughness values of 15 to 20 percent. The pressure oscillations were thought to be caused by contaminants in the hydrazine, such as, aniline. An effort to bake out possible catalyst bed contaminants under vacuum with a heat lamp resulted in an autodecomposition of the hydrazine entrapped in the fuel valve. Thus, the tests were terminated after 60.2 hr of run time due to a blockage in the propellant feed tube. Disassembly and inspection of the thruster and its catalyst showed that the injector tube became plugged with Teflon from the propellant valve seat, and the catalyst had suffered some poisoning from iron and nickel metals which were the result of a contaminated barrel of hydrazine which inadvertently had been used during the tests. Consequently, the actual "end of life" due to engine roughness was never reached. The maximum calculated roughness near the end of testing was only in the 6 to 7 percent range. With only 2 percent of the catalyst bed compression spring life remaining, it is most likely that if the test had continued, the engine roughness would increase as the catalyst was depleted and voids resulted. It should be noted that the inadvertent metal contamination of the catalyst may have accelerated the catalyst loss rate and the life may be somewhat great than reported herein. The thruster had accrued over 4.8×10^6 N-sec (1.1×10^6 lb-sec) of total impulse before the injector tube was blocked.

REFERENCES

1. Holcomb, L.; Mattson, L.; and Oshiro, R.: The Effects of Aniline Impurities on Monopropellant Hydrazine Thruster Performance. AIAA Paper 76-659, July, 1976.

2. Emerick, R.: Report on the Testing of the 25 lbf Long Life Thruster for Use on Boeing Space Station. SVHSER 9810, Appendix C, Boeing Aerospace Co., Huntsville, AL, Oct. 1985.

3. Emmons, D.L. and Neish, J.S.: Advanced Development Program for Long-Life Monopropellant Hydrazine Engines. AFRPL-TR-79-68, May 1980. (Avail. NTIS, AD-B047431L.)

4. Tolentino, A, III and Grotter, R.J.: Advanced 5 lbf Engine Demonstration. AFRPL-TR-84-008, Mar. 1984. (Avail. NTIS, AD-B082508L.)

5. Disassembly and Inspection of Rocket Research Advanced 5-lbf Hydrazine Engine. Report 82-R-885, Rocket Research Co., Redmond, WA, Aug. 1982.

TABLE I. - LIFE PERFORMANCE TEST OF HYDRAZINE THRUSTER

Test type	Number of cycles	Total time, sec	Total impulse	
			N-sec	lb-sec
Health check	287	174	3.9×10^3	870
Pulse, sec				
0.1 on/0.4 off	5000	500	1.1×10^4	2 500
1 on/2 off	5000	5 000	1.1×10^5	25 000
10 on/20 off	100	1 000	2.2×10^4	5 000
20 on/10 off	1951	39 200	8.7×10^5	195 100
100 on/5 off	1193	119 300	2.7×10^6	596 500
Steady state				
5 sec	11	55	1.2×10^3	275
1000	24	23 379	5.2×10^5	116 895
5670	5	28 350	6.3×10^5	141 750
Totals		216 778	4.82×10^6	1 083 890

TABLE II. - CHEMICAL ANALYSIS OF NOMINAL IMPURITIES OF TEST HYDRAZINE

Element	Percent by weight
Hydrazine (N_2H_4)	99.050
Water (H_2O)	0.344
Ammonia (NH_3)	0.265
Aniline ($C_6H_5NH_2$)	0.337
Iron (Fe)	0.0006
Chloride (Cl-)	0.0003
Carbon dioxide (CO_2)	0.0028
Nonvolatile residue (NVR)	0.0039
Trace organics (OHC)	0.0075

TABLE III. - PARTICLE SIZE ANALYSIS OF THRUSTER

Particle size, mesh number	Outer bed weight, g	Percent	Inner bed weight, g	Percent
30	9.17	78.85	4.21	79.43
30-45	2.12	18.23	.96	18.11
45-50	.11	.95	.03	.57
50-60	.08	.69	.04	.75
Total fines	.15	1.29	.06	1.13

TABLE IV - THRUSTER CATALYST BED METALS ANALYSIS

Metal	Inner bed, percent	Outer bed, percent	Minimum detection limit, percent	
			Inner bed	Outer bed
Fe	0.13	0.075	-------	-------
Mn	(a)	(a)	0.0026	0.0038
Cr	(a)	(a)	.0039	.0057
Co	(a)	(a)	.0065	.0095
Ni	.11	.056	-------	-------
Cu	(a)	(a)	.0026	.0038
Zn	(a)	(a)	.00065	.00095
Mo	(a)	(a)	.0065	.0095

[a]Below minimum detection limit.

ORIGINAL PAGE IS
OF POOR QUALITY

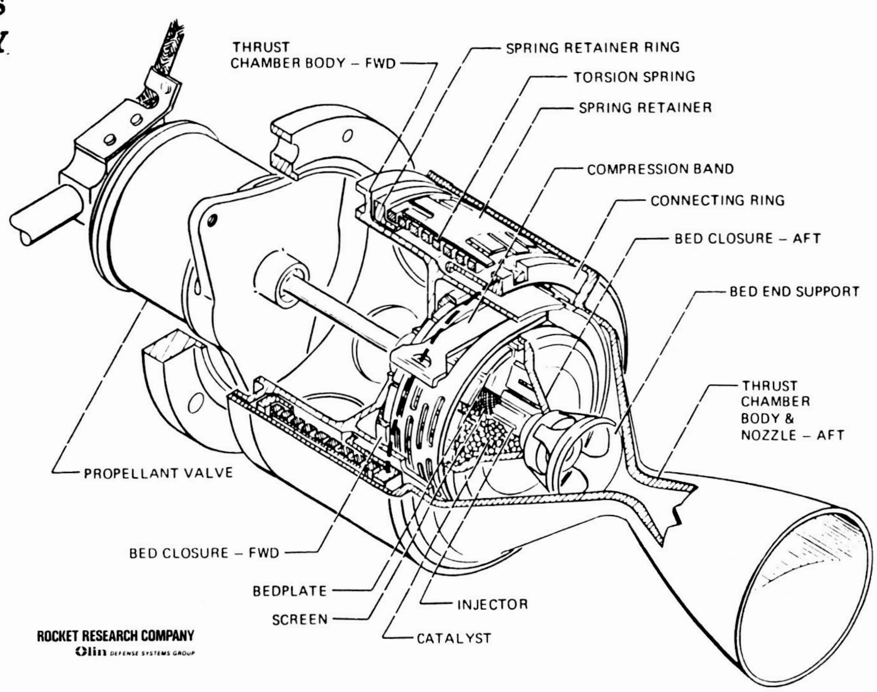


FIGURE 1. - ROCKET RESEARCH 22-N (5-LBF) THRUSTER.

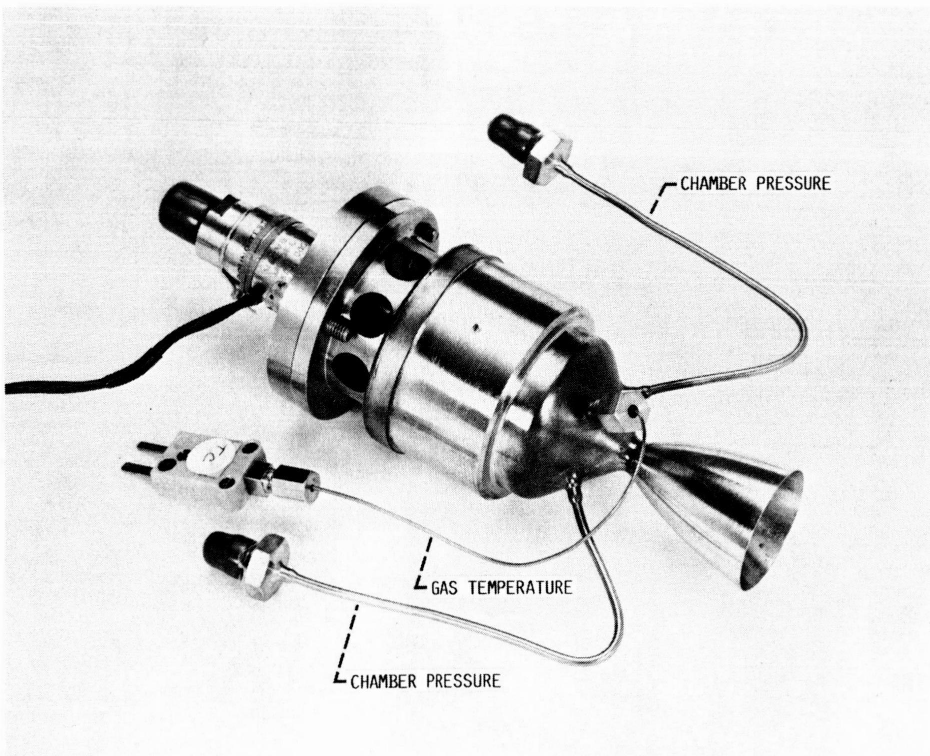
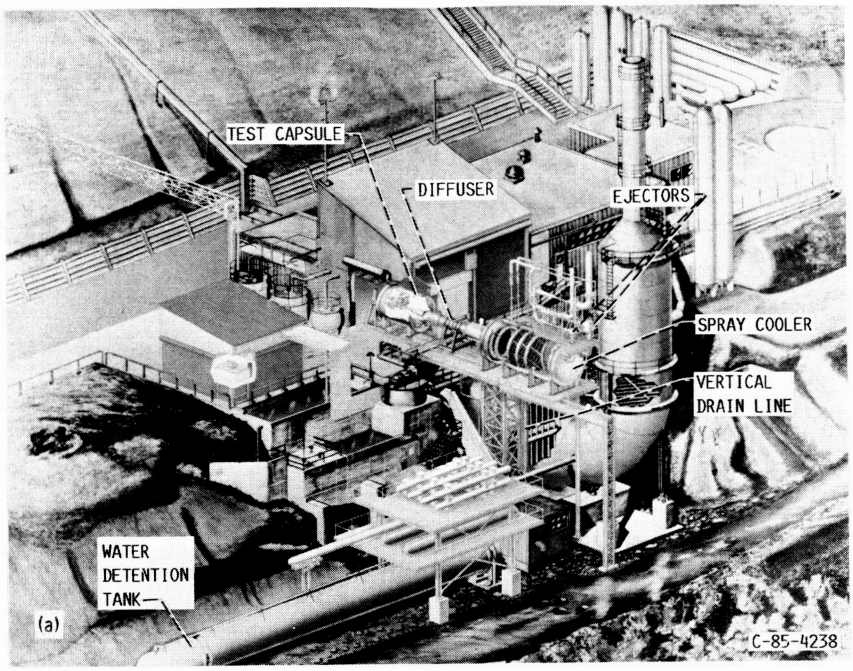
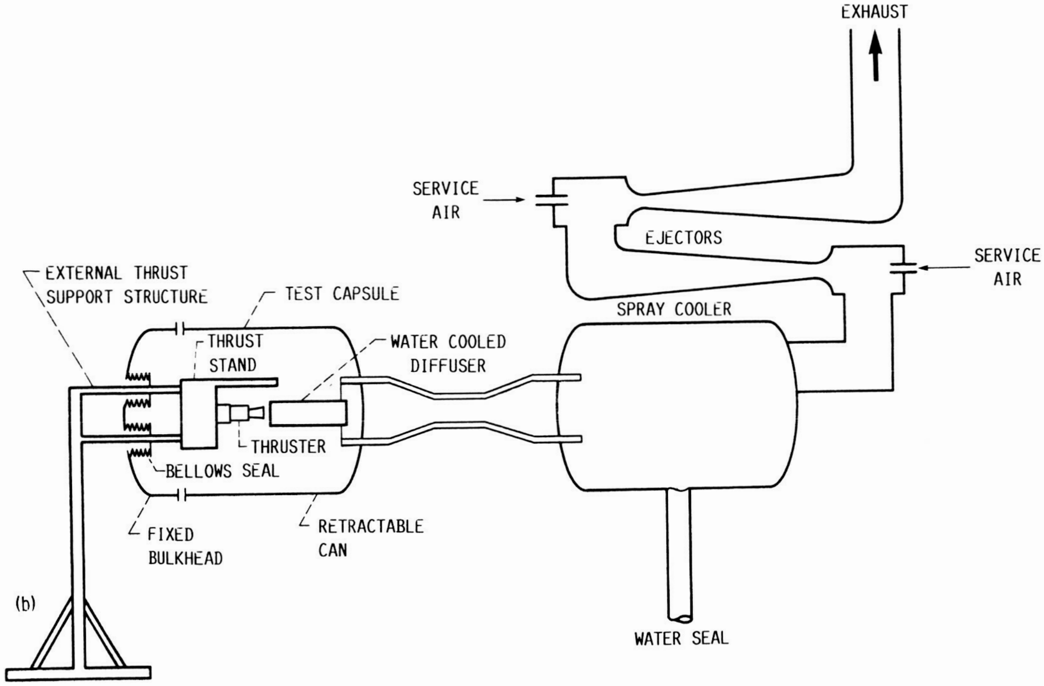


FIGURE 2. - PHOTOGRAPH OF HYDRAZINE THRUSTER.



(a) CUTAWAY VIEW OF ALTITUDE TEST FACILITY.



(b) SCHEMATIC OF ALTITUDE TEST FACILITY AS USED FOR HYDRAZINE TESTS.

FIGURE 3. - NASA LEWIS RESEARCH CENTER ROCKET ENGINE TEST FACILITY (RETF).

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

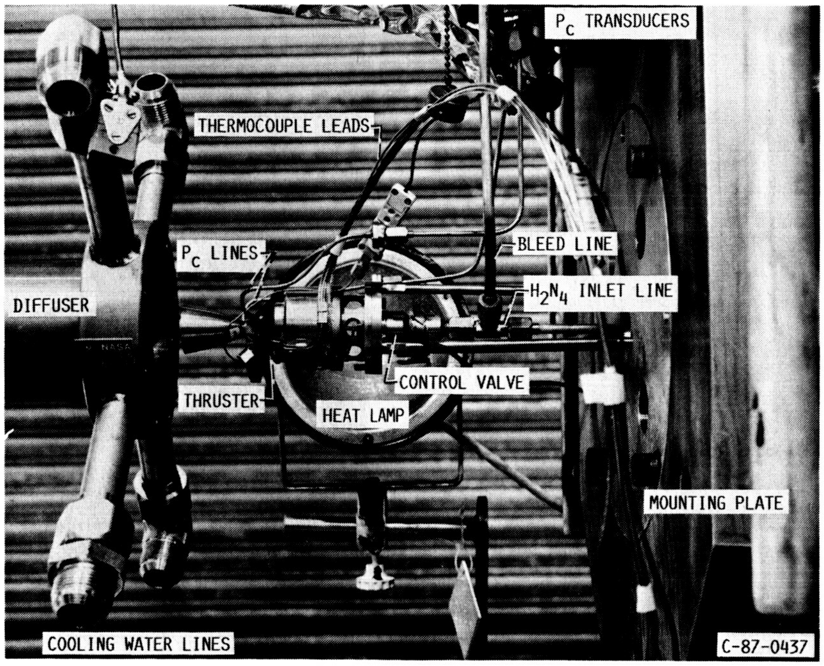


FIGURE 4. - HYDRAZINE THRUSTER MOUNTED IN ROCKET ENGINE TEST FACILITY.

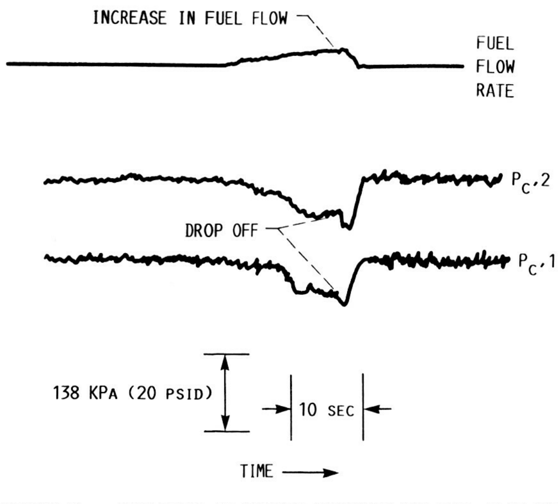
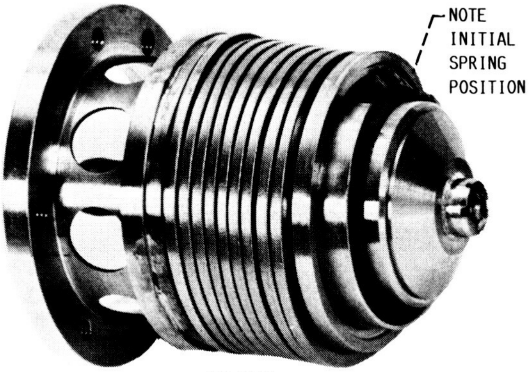
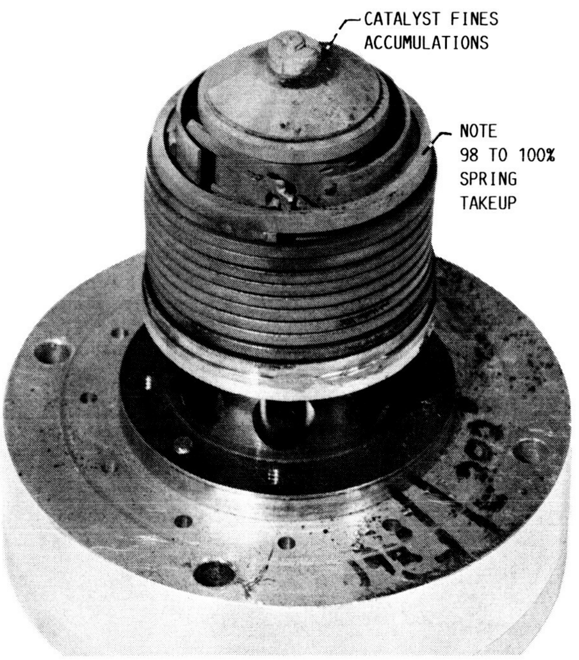


FIGURE 5. - VARIATION OF CHAMBER PRESSURE AND FUEL FLOW RATE TYPICAL OF HYDRAZINE "WASHOUT" PHENOMENON.



PRE-TEST



POST-TEST

FIGURE 6. - SPRING-LOADED ASSEMBLY FROM 22-N (5-LBF) THRUSTER BEFORE AND AFTER TEST.

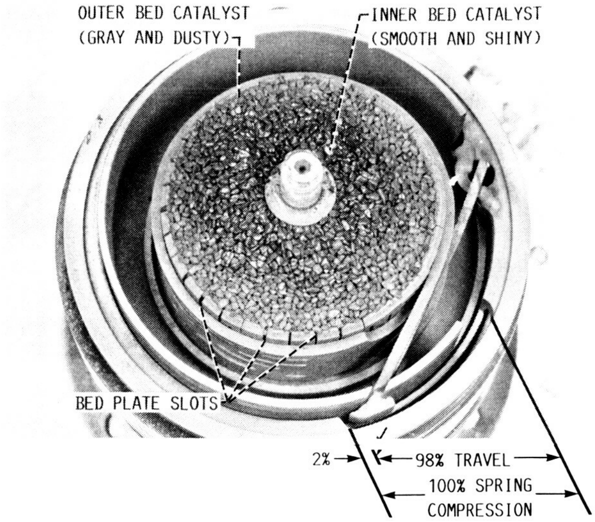


FIGURE 7. -22-N (5-LBF) SPRING-LOADED THRUSTER POST-TEST CATALYST BED DETAIL.

FIGURE 8.- 22-N (5-LBF) SPRING-LOADED THRUSTER REMAINS OF A TEFLON VALVE SEAT EXTRUDED THROUGH INJECTOR ORIFICES.

ORIGINAL PAGE IS
OF POOR QUALITY

NASA National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-100232		

4. Title and Subtitle	5. Report Date
A Life Test of a 22-Newton (5-lbf) Hydrazine Rocket	
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
P.R. Meng, S.J. Schneider, C.J. Morgan, R.E. Jones, and D.A. Pahl	E-3857
	10. Work Unit No.
	506-42-31
9. Performing Organization Name and Address	11. Contract or Grant No.
National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135-3191	
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Technical Memorandum
National Aeronautics and Space Administration Washington, D.C. 20546-0001	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared for the 1987 JANNAF Propulsion Conference, San Diego, California, December 15-17, 1987.

16. Abstract

Life tests were conducted on a 22-N (5-lb) hydrazine rocket thruster which incorporates the latest technology to obtain long life from the catalyst bed. A spring mechanism surrounding the catalyst bed continually applies compression to the catalyst bed to prevent the formation of any void channels. The thruster was instrumented and then installed in a high altitude facility at the NASA Lewis Rocket Engine Test Facility. The Rocket Research thruster was tested over an operational cycle of both steady-state and pulse firing which simulated a possible Space Station duty cycle. The thruster ran as expected for about 40 hr, or 3.2×10^6 N-sec (7.2×10^5 lb-sec) total impulse. Subsequently, some thrust chamber pressure decreases were noted during long steady-state test periods. After 60.2 hr of run time, the tests had to be terminated due to a blockage in the propellant injector tube which occurred during heating of the thruster by a heat lamp. The thruster had accrued over 4.8×10^6 N-sec (1.1×10^6 lb-sec) of total impulse before the injector tube was inadvertently blocked. After disassembly and inspection of the thruster, a chemical analysis of the catalyst indicated that iron and nickel metals had poisoned some of the catalyst, thereby, causing a degradation in performance. It was determined that a contaminated or "pink" barrel of hydrazine was the source of the metal poisoning. An examination of the catalyst bed compression spring indicated that approximately 2 percent life remained. It is possible that the use of contaminated hydrazine may have caused the catalyst loss rate to accelerate and the thruster life may be greater than reported in this paper.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Hydrazine rocket thruster Life test Catalyst poisoning	Unclassified - Unlimited Subject Category 20

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of pages	22. Price*
Unclassified	Unclassified	11	A02

NASA FORM 1626 OCT 86

*For sale by the National Technical Information Service, Springfield, Virginia 22161