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U. S. A R M Y TRANSPORTATION RESEARCH COMMAND FORT EUSTIS, VIRGINIA

TREC TECHNICAL REPORT 61-45

SMALL ROCKET LIFT DEVICE PHASE I

DESIGN, FABRICATION AND STATIC TESTING

Task 9R38-11-009-14

Contract DA 44-177-TC-642

MARCH Aprit 1961

Prepared by:

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BELL AEROSYSTEMS COMPANY Buffalo, New York

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Contract No. DA 44-177-TC-642

Service Strategy and Service Ser

March 1961

SMALL ROCKET LIFT DEVICE - PHASE I DESIGN, FABRICATION, AND STATIC TESTING

15 August 1960 to 23 December 1960

andell F. Moore

Wendell F. Moore SRLD Technical Director

Prepared by:

BELL AEROSYSTEMS COMPANY Buffalo, New York

for

U. S. ARMY TRANSPORTATION RESEARCH COMMAND FORT EUSTIS, VIRGINIA

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FOREWORD

The prosecution of a research and development program involving the direct application of rocket power to man, thus permitting him a limited range of flight, requires the dedicated efforts of many specialists. Through the generous contribution of knowledge, advice, and time of such men, the SRLD Phase I program has been remarkably successful.

The USATRECOM has assigned Mr. Robert Graham as Project Officer; his understanding help and advice have been of great value. Mr. Wendell Moore serves as Technical Director for Bell Aerosystems Company. Acknowledgement is made of the excellent analyses by Messers C. Henderson and J. Kroll of Stability and Control, Mr. S. Czarnecki of Reliability aspects, Mr. M. Drexhage for the excellent gas generator design, and Mr. E. Ganczak for his overall system design efforts which have been a large factor in producing results on schedule.

Phase I of the SRLD program was initiated on 10 August, 1960, and was completed on schedule 23 December, 1960.

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LIST OF SYMBOLS

| Symbol | Unit | |
|-------------------|----------------------|--|
| bȝ | lb/ft/sec | artificial damping applied to stabilizer- mass |
| ^b N | ft-lb/rad/sec | damping of control nozzle |
| BT | °F | insulation barrier temperature (cold side, left ring attachment) |
| C* | ft/sec | characteristic exhaust velocity |
| d3 | ft | distance from stabilizer mass to nozzle gimbal |
| EXT | °F | exhaust temperature (3 feet from nozzle) |
| F | lb | thrust |
| F _{corr} | lb | thrust (corrected to 410 psig feed line pressure) |
| FLP | psig | feed line pressure |
| FLT | °F | feed line temperature |
| GGP | psig | gas generator pressure (corrected to 410 psig feed line pressu ອ) |
| GGT | °F | gas generator temperature |
| IN | slug-ft ² | moment of inertia of nozzle about gimbal axis |
| I _{sp} | sec | specific impulse |
| I 1 | slug-ft ² | moment of inertia of upper torso about hip |

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LIST OF SYMBOLS (CON1)

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in which

| Sy | nbol | Unit | |
|-------------|--|--|--|
| · R | NP | paig | right nozzle pressure |
| R | NT | ₫ ₽ | right nozzle temperature |
| .1 | P | paig | tank pressure |
| 1 | R | lb | total thrust |
| . 1 | 8 <u>1</u> | 2 2 2 1 | tube skin temperature (6 inch from gas generator) |
| T | 82 | . * 7 . | tube skin temperature (at tube bend) |
| 3 | 63 | Ĩ₽ | tube skin temperature (3 inch from nozzle) |
| . V | V | lb/sec | weight flow |
| V | corr | lb/sec | weight flow (corrected to 410 psig feed line pressure) |
| V | Va | rad/sec | natural frequency of stability augmentation |
| .3 | C C | ft | lateral displacement |
| 8 | ; | ft/sec ² | gravitational acceleration |
| x | | | |
| | | .inches | display lateral displacement |
| 8 | P | inches psi | display lateral displacement differential pressure |
| ع ۲ | p c | inches psi degree | display lateral displacement differential pressure manual control deflection |
| ع ۲ ۲ | | inches psi degree degree | display lateral displacement differential pressure manual control deflection stability augmentation system control deflection |
| ع ع ر | | inches psi degree degree ft-lb/rad ² /sec ² | display lateral displacement differential pressure manual control deflection stability augmentation system control deflection damping ratio of stability augmentation system |
| ع ج ا | p c b n | inches psi degree degree ft-lb/rad ² /sec ² rad/sec | display lateral displacement differential pressure manual control deflection stability augmentation system control deflection damping ratio of stability augmentation system undamped natural frequency of stability augmentation system |

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LIST OF SYMBOLS (CONT)

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| Symbol | Unit | |
|-------------------------|----------------------|--|
| I2 | slug-ft ² | moment of inertia or lower torso about hip socket |
| κ ₁ | ft-lb/rad | hip spring constant |
| κ _N | ft-lb/rad | stiffness of control nozzle |
| К8 | lb/ft | spring constant of stabilizer spring |
| LNP | psig | left nozzle pressure |
| LNT | °F | left nozzle temperature |
| LP | psig | line pressure |
| М | ft-lb. | rolling moment |
| 1 ₁ | ft | distance from nozzle gimbal axis to upper torso center of gravity |
| 1 ₂ | ft | distance from upper torso center of gravity to hip socket |
| 13 | ft | distance from lower torso center of gravity to hip socket |
| 1 ₅ | ft | distance from body centerline to stabilizer mass |
| m ₁ | slugs | mass of upper torso |
| ^m 2 | slugs | mass of lower torso |
| mg | slugs | stabilizer mass |
| P _C Abs Corr | r | chamber pressure (corrected to absolute) |
| PFT | °F | propellant feed temperature |
| q 1 | degree | roll angle of upper torso (above hip socket) viii |

LIST OF SYMBOLS (CONT)

| Symbol | Unit | |
|----------------|--------|--|
| q 2 | degree | roll angle of lower torso (below hip socket) |
| δ _n | degree | nozzle deflection |
| θ | degree | stick deflection |

SUMMARY

In answer to a generalized requirement for increased mobility of the foot solider, an approach has been conceived wherein small rocket units are attached directly to an individual to provide him a short flight capability. An analytical study of the feasibility of such a system has revealed that such a device can be built with characteristics of reliability, stability, and controllability, and one which would be safe for operation by relatively inexperienced personnel.

To substantiate the theoretical investigations and captive flight tests utilizing nitrogen gas, it was deemed necessary to build a manned freeflight feasibility model of such a device and flight test it. Toward this end, Bell Aerosystems Company was awarded Contract No. DA-44-177-TC-642 to perform this task under the direction of the U.S. Army Transportation Research Command (TRECOM), Fort Eustis, Virginia.

The Contract Work Statement for this task was divided in two distinct phases. Phase I requires the design, fabrication, component testing and assembly of the Small Rocket Lift Device, followed by an engineering report of this work. Phase II requires static test firings of the assembled unit, tethered and free-flight testing with a human operator to determine the overall feasibility, performance, safety and utility of such a device, with adjustments and modifications as required to achieve satisfactory operation. A Phase II engineering report is to be issued along with a documentary movie of the flight test program.

The general approach to the design of the SRLD is to mount a hydrogen peroxide rocket propulsion system on a molded Fiberglas corset, shaped to fit the body of the operator. Underarm lift rings are attached to the corset through a central, laterally-pivoted joint at the back of the operator's neck. Two handles attached to the rings extend forward for control purposes. Actual lift is provided by two gimballed rocket nozzles, one mounted on each side of the operator outboard of the arms and above the center of gravity. The nozzles are fed by a central gas generator controlled by a squeeze throttle at the operator's right hand.

Flight stability and control of this feasibility model can be achieved by any combination of three methods; namely,

- 1. Pure kinesthetic control by body motions.
- 2. Roll damping only by automatic outward lateral gimballing of the nozzles when excited by lateral rotational accelerations.
- 3. A control stick mounted on the left forward arm which operates the gimballed nozzles for pitch, roll, and yaw.

Figure 1 is a photo of the actual SRLD.

During this Phase I period, all propulsion system components were designed, procured and tested on schedule. No major difficulties were encountered. Nozzle positions and control deflections were determined during a stability and control analysis with the aid of a "REAC" analog computor. Reliability aspects of the SRLD were compiled and determined as required. Human factors efforts during this period consisted of determining operator's body-mass data, flight control analysis and preparation of a tethered-flight test plan.

As a result of the successful component developments and system tests it was concluded that the system design was both safe and reliable enough to proceed with manned tethered and free-flight testing of the SRLD.



Figure 1. Small Rocket Lift Device - Left Side View

CONCLUSIONS

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The results of component design and testing as well as cold-flow system testing as reported herein indicate that the SRLD system as developed to date, will satisfy the requirements of safety and reliability necessary for manned flight tests.

RECOMMENDATIONS

It is recommended that Phase II of the program involving hot firing of the SRLD system and manned tethered and free-flight tests proceed immediately, utilizing the system as developed to date.

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I. SYSTEM DESIGN

The fundamental purpose of designing and testing an SRLD as set forth in the contractual Statement of Work is to determine the feasibility of attaching a controlled rocket system to a man for the purpose of transporting him over relatively short distances. No particular effort was to be expended to optimize the system; therefore, proven components were used wherever possible. Toward this end, Bell Aerosystems has designed and constructed such a device under the direction of U.S. Army, TRECOM.

Some of the fundamental problems facing the designer of such a device are: The rocket thrust must be manually throttled from zero to one hundred per cent to provide adequate altitude control. The operator must carry sufficient propellant to provide something in the order of 30 seconds of thrust time, and to prove the feasibility of various maneuvers. Further, controls must be provided to direct the thrust of the individual nozzles as required, to transport the operator to his desired target.

Safety factors must be considered very carefully. Things to be considered here are the effects of high-temperature exhaust steam in close proximity to the operator's body, the range of controllability, and due to the short lift time that is practical in such a device, a propellant warning system must be incorporated. Another consideration involving safety is that of distributing the heavy load of the SRLD properly about the operator's body.

After taking some of the foregoing considerations into account it was decided as a result of study at Bell, and elsewhere, to design the SRLD body harness in the form of a corset. In order to be certain that this corset actually fit the operator and distributed the load properly, a plaster cast was made of the operator's body, and from this a male model of the plaster cast was made. The male model was built up one inch larger than the operator's actual body shape to allow for one inch thick padding to distribute the load evenly around the waist and buttocks. After completion of the plaster mold, the corset itself was laid upon it, utilizing Fiberglas cloth impregnated with epoxy resin. This was then cured overnight at room temperature. The steps depicting the fabrication of this Fiberglas corset are shown in Figures 2 and 3.



Figure 2. Plaster Molding Operation

a.



Figure 3. Three-Quarter Front View of Mockup

Careful consideration had to be given to the selection of the padding which lined this Fiberglas corset. Numerous materials were investigated. Among them being Dow Corning "Ethafoam", U. S. Rubber "Ensolite", and "Rubatex" manufactured by the Rubatex Division of Great American Industries Inc. Ethafoam is a foamed cellular Polyethylene material. The latter two are foamed polyvinyl chloride materials. All of the materials were evaluated for firmness, impact sensitivity, and bulk density. They were all immersed for at least 12 hours in 90 percent hydrogen peroxide to determine what, if any, reaction took place. The test data on these materials is presented in one of the preliminary test reports in Appendix I. Dow "Ethafoam" was selected for the padding of the SRLD corset for two fundamental reasons:

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- 1. No chemical reaction occured during immersion for 24 hours in 90 percent peroxide.
- 2. The extremely low density of two pounds per cubic foot made it a desirable material for this application.

Another fundamental design consideration was how to lift the human operator. It was decided to use underarm lift rings as a result of past experience in experimenting with a nitrogen-powered rocket belt.

These rings were provided with control arms extending forward from the bottoms with hand control grips at each end. Underarm lifting admittedly is not the most comfortable method of lifting a human being; however, due to the short flight time of such a device, this was a very convenient and compact method of achieving this end. Further, it allows freedom of the operator's arms, shoulders, torso, and legs for kinesthetic control purposes. These lift rings were also padded with one inch thick "Ethafoam" tubing over the one inch diameter rings.

The hydrogen peroxide-powered propulsion system was then designed as a complete package in itself and mounted on a lightweight frame which in turn was bolied to the back of the Fiberglas corset at three points. The gas generator was attached to the top of this frame at about the level of the operator's neck by means of a radial pivot bearing. The purpose of the bearing is to allow the operator to shake or maneuver his shoulders laterally for lateral stability and control purposes. A flexible line is provided from the propellant tanks outlet to this moveable gas generator and throttle valve assembly. Two insulated outlet tubes were attached to the bottom of the gas generator to supply the two nozzles which were placed on each side of the operator, approximately 15 inches outboard of the

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operator's center line. These nozzles were designed with integral gimbals and high-temperature seals in order to permit thrust vector control during flight.

Three distinct methods of control of the SRLD are provided for experimental purposes, namely:

- 1. Pure kinesthetic control by body motions.
 - 2. Roll damping only by automatic outward gimballing of the nozzles, when excited by lateral rotational accelerations.
 - 3. A control stick mounted on the left forward arm which operates the gimballed nozzles for pitch, roll and yaw.

The control stick is suspended in a vertical position at the end of the left arm extension by means of a spherical bearing. A mechanism was devised which permits roll, pitch and yaw control through a single hand grip. Control motions are transmitted to the gimballed nozzles through flexible push-pull controls. The maximum stick deflection is 15 degrees from center. No artificial feel or centering is provided at the present time.

The center of gravity relationships to the nozzle positions were designed according to the recommendations resulting from the stability and control analysis described elsewhere in this report. Figure 4 is a graphical illustration of this relationship.

The nozzle maximum deflection for full stick deflection was designed to be adjustable so that full maximum nozzle deflections of 3, 6, or 9 degrees could be explored during the flight test operations.

The automatic stability augmentation device was designed to actuate the nozzles about the gimbal when lateral rotational accelerations are experienced by the pilot during flight. A lateral acceleration toward the left would automatically flip the left nozzle outward tending to stabilize the system. The nozzles are blocked at the gimbals from turning inward toward the operator's body. Provision was made to lock both the stick and the nozzles in the neutral position for the purpose of exploring pure kinesthetic flight control.

The circular lift rings around the shoulders are provided with hinged sections at the front. These are lifted upward and snapped into place by



Figure 4. Man-Machine C.G. Relationship

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means of specially-designed quick release fittings. A quick-release safety belt was procurred and installed around the waist of the Fibreglas corset in such a manner that it would tighten about the operator's stomach. It was found during testing of the mock-up, that it was desirable to add a "belly plate" from a stiff, 1/s inch thick rubber material to support the abdomen while the operator was being lifted by the SRLD. Entrance to the SRLD is a matter of backing into the corset, snapping the quick release links into position and tightening the safety belt. Several different designs of throttle control were considered during the design phase. The one chosen for the first trials was a squeeze-type hand throttle placed at the end of the right arm extension and formed to fit around the knuckles of the right hand with the palm grip at the aft side. Squeezing this throttle control applies thrust in a predetermined fashion controlled by the throttle valve from zero to maximum. Releasing the throttle grip reduces the thrust. A suitable return spring is provided to return the throttle valve and the grip to zero.

Since the maximum flight time of this particular feasibility model of the SRLD is in the order of 30 seconds, a flight time or propellant remaining warning system had to be provided to signify flight time remaining to the pilot. Many types of systems were considered. Obviously, the best and most accurate type would be one based upon actual measurement of the propellant remaining in the tanks. However, such a system becomes quite expensive and complicated and was determined unnecessary during this phase of the program. The system actually selected and used in this SRLD is one that is based on theoretical propellant consumption. Both auditory and visual signals are provided to the pilot at 10 seconds before propellant burnout. The device fundamentally consists of a cammed chronometric DC timing motor connected to an electronic audio signal generator and warning light switches. The signal generator provides a "beep-beep" type of tone at one second intervals beginning ten seconds before theoretical burnout. This tone is provided to the operator through a head set in the crash helmet. The cam-actuated switches cause a red light mounted on the helmet at about the bridge of the pilot's nose to flash concurrent with the auditory signal. During initial hot-firing tests of the gas generator and nozzle assembly, this unit was tested. It was found that any variation provided in the auditory signal, both frequency and gain, could not actually command the operator's attention. However, in every case the red light at the edge of the operator's peripheral vision did command his attention to take action. Therefore, even though this auditory device has been retained, we have concluded that it is of no value in this program, fundamentally, because of the high noise level of the SRLD itself.

A photograph of this propellant warning device is shown in Figure 5. A schematic diagram of this device is shown in Figure 6.

Preliminary noise level investigations were made during the gas generator test cell firings. During Run No. LD-22 (see Appendix IV) a meter located where the pilot's head would be read 131 decibels. A noise level of 133.5 decibels occurred when the meter was placed between the nozzle exits on Run No. LD-28.

Concern was evidenced by many people over the possibility of the pilot being burned about the legs and feet from the high-temperature steam of the rocket exhaust during operation. It was considered that the worst condition which could occur would be the heat generated during a full duration equivalent tiedown run. During the reliability testing program of the gas generator and nozzle assembly, thermocouples were placed beneath one of the nozzles at a distance equivalent to the ground level with the operator standing. One thermocouple was placed directly on the center vertical line of the nozzle, the second and third were placed 18 inches inboard and outboard of this center. The maximum temperature encounted during this test was 400°F. As a result of these tests it was determined that no particular harm would come to the operator provided he at least had a pair of heavy trousers and boots on. A schematic of this test set-up along with a small table indicating the maximum temperatures achieved is shown in Figure 7. In addition to the squeeze type throttle control it has been decided to test a motorcycle type of throttle control. A Harley-Davidson motorcycle control grip was therefore purchased and is being modified to actuate the push-pull control of the SRLD throttle. During the flight test program both throttles will be evaluated. The pertinent dimensions of both throttle control systems are given in Figure 8,

No particular effort was made during the design of this feasibility model to optimize the system so far as weight was concerned. For example, an existing ICC-approved high pressure nitrogen bottle was utilized for source gas in the propulsion system, and two existing Air Force breathing oxygen bottles were utilized for propellant tanks. As a result the SRLD empty weight as it stands today, in flight-ready condition, is 79.57 pounds. The operator's weight, ready for flight including suit and helmet, stands at 154.4 pounds. Forty-seven pounds of hydrogen peroxide are loaded in the propellant tanks and two pounds of nitrogen gas charged in the high pressure cylinder. Taking all the foregoing into account, the take-off weight of the SRLD is 283.97 pounds. Table 1 is a detailed weight breakdown of the SRLD system.





Figure 6. SRLD Propellant Timer - Schematic Diagram

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Figure 7. Exhaust Temperature Survey

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TABLE 1

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SRLD WEIGHT BREAKDOWN

| Item No. | Part No. | Part Name | Weight (pounds) |
|-------------|------------------------|---|--------------------|
| 1 | AN6025BX415-21 | No Storage Bottle | 16.25 |
| 2 | MS28889-1 | Hi-Press Fill Valve | .16 |
| 3 | 2725-3 | Hi-Press Gage | .15 |
| 4 | 8060-472001 | Shutoff Valve | .54 |
| 5 | 8060-472004 | Filter | .24 |
| 6 | 8123-472010 | N ₂ Regulator | 1.65 |
| 7 | 8123-472003 | Check Valve | .19 |
| 8 | 8123-472015 | Press. & Vent Valve | .50 |
| 9 | 8060-472122 | Relief Valve | .36 |
| 10 | 1525- 31688 | Lo Press Gage | .30 |
| 11 | 8123-471001 | Storage Tank Assy H ₂ O ₂ | 12.25 |
| 12 | 8123-472005 (2) | Manual H2O2 Fill, Drain & Bleed Valve | .28 |
| 13 | 8123-472002 | Throttle Valve | 1.40 |
| 14 | 8123-470001 | Gas Generator Assy | 5.69 |
| 15 | 8123-470040 (2) | Gimballed Nozzle Assy | 2.40 |
| 16 | R22533-10-0180 | Flexible Hose | .60 |
| 17 | 8123-460009 | Harness & Insulation | 5.50 |
| 18 | 8123-460008 | Support Frame Assy | 2.30 |
| 19 | 8123-460007 | Lift Support Assy (Minus Gas Gen.) | 10.80 |
| 20 | | Control Cables (Including Throttle) | 5.25 |
| 21 | | Throttle Handle | .86 |
| 22 | | Control Stick Assy | 1.65 |
| 23 | | Belt & Abdominal Support | 1.25 |
| 24 | | Upper Tether Tiedown Support, | 3.00 |
| 25 | | Battery & Timing Equipment | 4.00 |
| 26 | | Plumbing & Miscellaneous Fittings | 2.00 |
| | | SRLD Empty Weight = | 79.57 lbs. |
| | Operator | | 141.00 |
| | Flight Suit | | 4.50 |
| | Insulated Underclo | thes | 1.25 |
| | Boots | | 4.40 |
| | Helmet | | 3.25 |
| | | Operator's Weight = | 154.40 |
| | | Propellant Weight = | 47.00 |
| | | Source Press Weight = | 2.00 |
| | | Takeoff Weight _= | 283.97 lbs. |

A special flight suit was designed and fabricated for the SRLD operator. This was done primarily from the standpoint of safety and secondly of obtaining good engineering data on the body and limb positions. The suit was designed to be worn over quilted "dacron" underwear and was fabricated in such a fashion as to draw the material tightly about the limbs and torso, so that body joints, leg angles, etc, would be readily detectable on the flight films for analysis purposes. The suit itself was fabricated from chartreuse-colored "Graylite" material, a polyvinyl-impregnated cloth. This material is suitable for use with raw hydrogen peroxide. Nine-inch insulated boots with a deep ripple, soft-rubber sole were procurred for the operator's use. These will afford the maximum protection from accidental ankle injuries, hard landings, and high temperature exhaust. Figure 9 is a photo of this flight clothing as worn by the operator.



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Figure 9. SRLD Flying Suit - Side View

II. PROPULSION SYSTEM

A simple pressurized 90% hydrogen peroxide propulsion system was chosen to power this feasibility model of the SRLD. Whenever possible, proven components were utilized to enhance the safety and reliability of the system. Referring to the photo-schematic (Figure 10), beginning at the bottom center is a standard high-pressure cylinder in which nitrogen sus is stored at 2100 psi. The bottle is charged through a standard aircraft-type hi-pressure fill valve and pressure is indicated to the operator by a miniature high pressure gauge. The stored gas flow into the system is controlled by a manually-operated N2 shutoff valve developed for the Mercury Project. This is followed by a high-pressure. 10-micron filter also developed for H2O2 systems on the Mercury Project. The filter flows into a Bell-modified Grove "Mitey-Mite" pressure regulator. The regulator is a normally-open, gasloaded dome type. A suitable check valve is provided at the outlet of the pressure regulator and eliminates any possible back-flow of H2O2 in the event of accidental source gas loss after propellant tank pressurization. Pressure to and from the propellant tankage assembly is manually controlled, by means of a "pressurize and vent" (3-way) valve. A 0-600 pai. peroxide-compatible tank pressure gauge is teed into the tank pressurization line just downstream of the "Press. & Vent" valve along with a tank pressure relief valve, set at 525 psi. The latter two valves are also Mercury components.

The propellant tankage system consists of two modified AF type D-2 breathing oxygen bottles tied together at the bottom by special bosses and a manifold. Located at one end of the manifold is a small shutoff valve. This valve is used to fill and drain the tankage system. Inserted in the top of each tank is a tube that is connected to another shutoff valve. This is the tank bleed valve. Those overflow tubes are inserted at a predetermined height to control the amount of ullage when the tank is filled. The propellant flows under a pressure of 450 psi from the center of the manifold through a flexible line to the throttle valve.

The throttle valve is a plunger and spool type valve. The spool has a series of orifices which when uncovered by the plunger varies the amount of hydrogen peroxide flow from zero to maximum flow to the gas generator. Peroxide flowing from the throttle valve is decomposed by catalytic action in the gas generator. The decomposed gases are directed through and expanded in the two exhaust nozzles to produce thrust proportional to the peroxide flow.



Figure 10. System Components - Photo Schematic

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The two exhaust nozzles are gimballed and are controllable for pitch, yaw, and roll by movement of the left hand grip if desired.

To actuate the propulsion system, the operator places the P and V valve in "Pressurize" posistion, opens the N₂ shutoff valve, and squeezes the throttle control.

After the initial 1.11d-up of the propulsion system was completed, it was chemically cleaned and filled with distilled water for test purposes. The actual pressurization and flow tests with distilled water were successfully completed without incident. Residual propellant, (water in this case) averages approximately 2 pounds when the first gas bubble goes through the gas generator feed line. The nitrogen supply pressure averaged about 900 psi at the end of liquid expulsion when the initial charge was 2100 psi. The modified Grove regulator pressure drop-off was within the expected values. Various types of pressurization and flow rate changes were tried. The purpose of these tests was to detect any possible malfunction tendencies of the system or components. No problems were encountered. The detailed test data for these water flow test reports are shown in Appendix II.

The completion of the foregoing system water flow test represented the final work requirement in Phase I of this contract. Phase II was begun with hot-captive firings in the test cell with a weighted plaster dummy. This will be followed by manned captive flight tests and finally manned free-flight tests.

SRLD PERFORMANCE SUMMARY

| Thrust | 280 lbs. nominal |
|---|-------------------|
| Throttle Range | 0 to 100% |
| I _{sp} (100% Thrust) | 120^{+} min. |
| Propellant (H ₂ O ₂) | 47 lbs. max. |
| N ₂ Source Pressure | 2100 psi |
| Tank Pressure | 4 50 psi |
| Relief Valve Pressure | 525 psi |
| Nominal Duration | \approx 22 sec. |

The following itemized list gives all the basic information and test regults of the individual components that are used in the propulsion system.

AN6025BX415-21 Nitrogen Storage Bottles

Certified material and test information were received from the vendor (Walter Kidde Company). The bottles were hydrostatically tested to 3500 psi. Permanent expansion was 0.2 cubic centimeters on one bottle and 0.5 cubic centimeters on the second bottle. One unit is mounted on the SRLD and the other is being held for a spare.

MS28889-1 High Pressure Charging Valve

This government standard part is satisfactory for service operation at 3000 psi, is fully developed, and is available from government-approved sources which are on the QPL list. Two of these units were cleaned and functionally tested. One item was installed on the SRLD and the other is being held for a spare.

2725-3 High Pressure Gauge 0-3000 psi

Two small gauges (0-3000 psi) were purchased from Rochester Manufacturing Company. These gauges were not compatible with hydrogen peroxide. However, due to the fact that they are used in the source gas system, they are considered acceptable. The gauges were processed chemically clean at Bell Aerosystems Company. Calibration curves of these gauges are presented in Figure 11.

8060-472001 Manual Nitrogen Shutoff Valve

This value is a manually-operated ball-type value which has been developed for use in H_2O_2 pressurizing gas systems. The operating range is 0 to 3000 psi., requires a rotary motion of 90 degrees, and approximately 12 inchpounds of torque. Leakage external and internal does not exceed 5 cc per hour and life is 1000 cycles.

Accountability of two of these units was transferred from the "Mercury" program to the SRLD program and to be used in the "as is" condition. Another unit was bought specifically for the SRLD program and is available for use. Pressure drop and flow data are shown in Figure 12.

8060-472004 Filter

This is a 10 micron, 304 stainless steel, convoluted wire mesh filter encased with an aluminum body developed for the Mercury Project. The operating pressure range is 0-3000 psi. Cycle life without structural failure is 2000 cycles with pressure applied from 0 to 3000 psi.







| STD | NO.1 | NO.2 |
|------|------|------|
| 500 | 600 | 580 |
| 1000 | 1000 | 1000 |
| 1500 | 1480 | 1480 |
| 2000 | 1960 | 1960 |
| 2500 | 2580 | 2580 |
| 3000 | 2950 | 2980 |

Figure 11. Calibration Curves of the SRLD Pressure Gauges


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Figure 12. Gas Flow vs $\triangle P$ (Hand Valve)

Two of these filters were transferred from the "Mercury" program to the SRLD program, to be used in the "as is" condition. An additional unit has been purchased and is now available. Figure 13 shows the gas flow test results at various inlet pressures versus pressure drops.

8123-472010 Pressure Regulator

Unless an extensive development program was authorized, Scott Aviation would not supply components for modification to meet the SRLD requirements. Consequently, an "off the shelf" Grove Regulator Company, Model 94X "Mitey-Mite" regulator was selected. Initial informal tests indicated that a balanced poppet design was required to reduce the regulated pressure drop during flow.

Two of these units were modified by Bell to incorporate this feature. See Appendix III for test data.

8123-472003 Check Valve

Contractor 60

A Spartan Aircraft check value of the size required for the SRLD had a minimum pressure drop of 30 psi. Spartan would not accept a contract to supply a unit with a maximum drop of 10 psi unless a development program was authorized.

A James, Pond, Clark "Circle Seal" check valve was selected and tested. The valve "as is" would not pass low reverse pressure leak tests because of the Teflon dynamic seal "O" ring. This was replaced by a Viton "A" 'O' ring and successfully passed flow and leakage tests. See Figure 14 for flow test results.

8123-472015 Pressure and Vent Valve

This is a manually-operated push-pull spool type valve designed for the Mercury Program. In the push position, it keeps the tank vented and shuts off source gas to the tank, and in the pull position it allows source gas to flow to the tanks and closes the overboard vent line. This valve has been developed for 100 cycle life operation and operates over a pressure range of 0 to 525 psi. It has also been designed for compatibility with hydrogen peroxide systems.

The accountability of two "Mercury" units (8060-472036) were transferred to the SRLD program. An additional unit is being manufactured solely for the SRLD program.



Figure 13. N₂ Gas Flow vs ΔP (N₂ Filter)

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Figure 14. N₂ Gas Flow vs ΔP (Check Valve)

Problems encountered with this value were "O" ring blow-out due to wire-drawing of the soft durameter silicone (DC 9711) "O" ring during pressurization, and maintaining the piston in the vent position because of the slight pressure unbalance.

The following modifications were made to the valves to overcome these problems: The first problem was overcome by changing the "O" ring compound to Viton "A" which has greater tear resistance. The second problem was resolved by adding a ball detent which held the piston in the tank vent position.

Pressure drop test data on this unit is shown in Figure 15.

8060-472122 Relief Valve

This is a spring-loaded soft-seat type valve designed for use in a hydrogen peraxide system for the Mercury Program. The life cycle is over 500 cycles. Cracking pressure range is adjustable from 500 to 600 psi and reseat from 450 to 550 psi. Leakage does not exceed 5 cc per hour at reseat and lower pressures. At fully opened positon, the valve will pass approximately 75 SCFM mitrogen gas.

Two of these units were procured from the "Mercury" program and are being used in the "as is" condition for the SRLD program. An additional unit is being manufactured for the SRLD program. The following test data was taken from the first unit.

| | Specified Pressure | 1 | 2 | 3 | 4 | 5 |
|-------------------|--------------------|-----|-----|-----|-----|-----|
| Cracking Pressure | 535-580 psi | 551 | 550 | 549 | 550 | 550 |
| Reseat Pressure | 480 psi Minimum | 525 | 523 | 524 | 523 | 523 |

Zero leakage after reseat up to 15 minutes was observed.

1525-31688 Low Pressure Gauge 0-600 psi

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'Two stainless steel gauges, 0-600 psi, purchased from U.S. Gauge Company for use in the hydrogen peroxide system were successfully cleaned and conditioned for peroxide service. See Figure 11 for calibration curve presentation.

8123-471001 Hydrogen Peroxide Storage Tank Assembly

Two sets of Hydrogen Peroxide tank assemblies were made from standard D_2 type oxygen bottles. One set was proof, fatigue and burst tested. See Figure 16. The other set was proof tested and is now installed on the SRLD.



8060-472-036 SELECTOR VALVE SN 202

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Figure 15. N₂ Gas Flow vs ΔP (Pressure and Vent Valve)

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Figure 16. SRLD Burst Test Tanks

The proof test pressure was 788 psi. Figure 17 presents the displacement and permanent set curves of the first set of tanks. Fatigue testing consisted of 2000 cycles of 0-525 psi pressure, during which no leakage occurred. On the burst test, at 1150 psi a crack developed in the weld at the left-hand outlet fitting. Figure 18 is a displacement and set curve derived from test data during burst test. Figure 19 shows the proof test displacement and permanent set curve of the set of tanks now installed on the SRLD.

8123-472005 Manual Fill, Drain and Bleed Valve (2 Required)

In order to reduce the weight and envelope configuration of the original 8060-472009 values it was decided to go to smaller value. A "Shrike" bleed value (59-472-275) was selected because of its size and weight (approximately 1/4 of the original value). For compatibility with hydrogen peroxide it was necessary to modify these values by removing the chrome plating from the needle detail. This value is also being used as a shutoff value in the fill bleed system.

8123-472002 Throttle Valve

Early in the design phase of the propulsion system, the throttling characteristics required for the SRLD were determined. It was desirable to attain approximately 70 percent thrust with approximately 35 percent of the initial throttle stroke, and to reserve the remaining 65 percent of the throttle stroke for vernier thrust control between 70 and 100 percent. This feature provides good, sensitive hovering control as propellant is utilized during the flight. The foregoing throttle valve characteristics are presented in the curve in Figure 20. Two additional characteristics assigned to the design of this valve were: positive shutoff at the end of the stroke, and low breakout and running friction to allow smooth throthing action. The valves were designed and fabricated by the National Water Lift Company of Kalamazoo, Michigan, Design, fabrication, preliminary test, and delivery was accomplished by them, on schedule. Tests at Bell confirmed that the throttling flow and shutoff characteristics of both valves were within specification tolerances, and they met 90 percent H2O2 compatibility requirements. However, when one valve was installed on the SRLD gas generator test stand for hot firing evaluation, trouble was encountered with high breakout friction, sticky operation and shearing of the shutoff "O" ring by the plunger. Tests were continued after removal of the shutoff "O" ring and inbrication of the "Viton" running "O" ring seals. The resultingleakage of 150 cc/min. at operating pressure was considered acceptable for temporary use. The second valve was returned to the vendor for redenim and rework as required. As a result, the following changes were made:



Figure 17. Proof Test Displacement and Permanent Set Curve, Burst Tanks

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Figure 18. Burst Test Displacement and Permanent Set Curve

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1. The shutoff "O" ring seal and groove were removed.

2. New, close tolerance plunger and spool were installed.

3. The flow annulus around the initial throttling orifices was removed.

4. Teflon-capped dynamic "O" ring seals were installed.

As a result of these changes the valve now works smoothly, with a treakout force of five pounds and running force of 3.5 pounds. Leakage in the shutoff position, at maximum operating pressure, is 1.6 cc/min.

The second value will be returned to NWL for rework and returned to Bell for additional testing.

8123-470001 Gas Generator Assembly

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The hydrogen peroxide gas generator is of a conventional design which has proven its reliability efficiency and endurance in many similar applications. The essential and performance-controlling component is the catalyst bed. Catalyst material is the Bell Type 7 catalyst screen.

Specific impulse varies somewhat when a rocket motor or gas generator is throttled from the design point. This factor must be taken into consideration when calculating theoretical SRLD flight times. For this pupose, curves of gas generator I_{SD} and flow rate versus thrust are presented in Figure 21.

The gas generator chamber is constructed of 347 stainless steel and of an all-welded design to avoid any possibility of leakage. A sufficiently large chamber volume downstream of the catalyst bed ensures an equal flow distribution into the two hot gas branches leading to the nozzles.

The external surface of the gas generator is enveloped by a perforated heat shield to avoid skin burns on accidental touch.

Test firing of the gas generator began in October 1960. The catalyst bed was conditioned for 250 seconds. Because no performance discrepancy was evident, it was decided to proceed immediately with reliability testing. A total of 88 firings were conducted with close monitoring of all performance parameters (see Appendix IV). Results of these tests are shown in Figure 22. The majority of these tests used the fixed nozzle configuration. However, because the test program was proceeding without complications, it was decided after Run 47 to install the flexible nozzles of the ball joint type into the system to





Figure 21. SRLD Specific Impulse and Flow Rate vs Thrust



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obtain information about their operating characteristics. Observed frictional forces were excessive and the nozzles were locked for the remainder of the reliability test program.

On Run 85 a test was made to determine what the maximum temperature of the feed line H_2O_2 would be if the SRLD were fired for 30 seconds and shutdown without purging or venting. This is a safety consideration. This temperature was found to reach a maximum of $170^{\circ}F$ at 22 minutes after shutdown and is considered safe. Figure 23 is a time-temperature curve from this test.

8123-470040 Gimballed Nozzle Assembly

The lift-producing nozzles are of the swivel type to provide flight control. The nozzles are fully gimballed and can be deflected in a complete circle at an angle of 9 degrees. However, an inboard stop prevents deflection towards the body of the pilot.

Figure 24 shows the design approach taken by Bell Aerosystems Company to develop a swivel-type nozzle.

Testing of the original ball joint flexible nozzles revealed high frictional forces under axial loads induced by internal pressures on the nozzle and inner race. These frictional forces are amplified by wedge action between the inner and outer race under axial load. The forces required to deflect the nozzles were found to be 150 to 300 inch-pounds at the end of a 30 second firing period, virtually resulting in seizing of the joint while hot. A redesign was immediately initiated with the following objectives.

- (1) Relocate the nozzle throat, axially, to balance the dynamic pressure forces of the convergent and divergent nozzle to a possible optimum to reduce axial loads.
- (2) Reduce ball joint diameter to a minimum to reduce the magnitude of unbalanced cross-sections and axial forces.
- (3) Utilize external gimbals to take axial loads and provide low-friction, high-temperature seals on the spherical surfaces between the two moving nozzle sections.

Design illustration "C" in Figure 24 was selected for fabrication. Cold actuation torque on these nozzles was very low with pressure on the seal adequate to seal properly. Subsequent hot firings showed that the friction feel of the gimballed nozzles seemed no different than the cold static "feel".



Figure 23. Feed Line Temperature Curve

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However, the friction level is deemed high enough to demand an excessive weight to overcome it, if the automatic stabilization system is to be used. Insomuch as this system is not deemed mandatory for safe flight control, it was decided to "wring out" the other methods of control and install this system later if required.

III. STABILITY AND CONTROL

Studies were made of the controlled lateral behavior of a man supported by the SRLD. System dynamics were instrumented on an analog computer and control inputs were provided by a human operator who responded to visual cues displayed on an oscilloscope (Figure 25). The analog studies indicated that a stability augmentation system may not be necessary for satistactory control. Control moments reduced from original design values resulted in highly improved handling characteristics. Preliminary Phase II tethered flight tests have not reached the stage where correlations between flight test observations and the computer studies can be made.

Early tethered flights on SRLD test rigs powered by compressed nitrogen nowed certain undesirable stability and control characteristics. Fore-aft pitching and translation were satisfactory but lateral translation and rolling motions were oscillatory and for the most part uncontrollable. In order to obtain a better understanding of the system dynamics, a mathematic model possessing some of the basic properties of a man supported by a rocket lifting device was simulated on analog computing equipment. Initial studies were concerned mainly with the effect of a stability augmentation scheme on the uncontrolled lateral behavior. Subsequent studies were then made to determine how certain parameters influenced the controlled behavior by a man whose task was to hove, and translate laterally. These latter studies are discussed in this report.

A. METHOD OF ANALYSIS

The model of the man-machine combination and stability sugmentation device used in this investigation is shown in Figure 26 along with the applicable equations of motion.

This model has an upper and a lower body connected by a torsional spring at a point corresponding to the hip axis. Rocket nonsies are located at the end of L-shaped arms assumed to be rigidly attached to the upper body. The upper body represents the man's upper torse, head, arms, propellant tanks, gas generator, values and tubing. The lower body represents the legs. Except for the hip spring, this model is similar to the one developed in Reference 2. Small-angle approximations were used in the derivations. Effects of variable mass and moment of inertia due to propellant consumption were neglected. The e n tions were instrumented on an analog computer.



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Figure 25. Control Simulation Test Setup

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 $I_{1} \ddot{a}_{1} - m_{1}g \mathcal{A}_{2} q_{1} - K_{1}(q_{2} - q_{1}) + 37.3 m_{1} \mathcal{A}_{2} \ddot{x} = \frac{T_{R}}{2} (\mathcal{A}_{1} + \mathcal{A}_{2}) \vartheta_{R}$ $I_{R} \ddot{a}_{R} + m_{2}g \mathcal{A}_{3} q_{2} + K_{1}(q_{2} - q_{1}) - 57.3 m_{R} \mathcal{A}_{3} \ddot{x} = 0$ $57.3 (m_{1} + m_{2}) \ddot{x} + m_{1} \mathcal{A}_{2} \ddot{q}_{1} - m_{2} \mathcal{A}_{3} \ddot{q}_{2} = T_{R} q_{1} + \frac{T_{R}}{2} \vartheta_{R}$ $\ddot{\vartheta}_{3} + 2\zeta \omega_{n} \dot{\vartheta}_{3} + \omega_{n}^{2} \vartheta_{3} = -\frac{\mathcal{A}_{5}}{d_{3}} \ddot{q}_{1}$ $\vartheta_{n}^{2} \vartheta_{c} + \vartheta_{3}$

Figure 26. Schematics of Man-Machine Combination and Stability Augmentation Device; Equations of Motion

Provisions were made for limiting the deflections of the stability augmentation system (δ_g) as a function of the nozzle control deflection (δ_c) . This relation is inherent in the control system design and is shown in Figure 27.

The human operator or pilot was required to control his motion based on observations of his position and motion displayed on an oscilloscope screen. Figure 28 is a schematic of the display and shows the image seen by the pilot. The image height was adjusted to slightly over 1/2 inch. Thus its height to displacement ratio would give the impression that the image represented a 6 foot rigid man.

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The method of analysis in Reference 2 did not employ a human operator. There, tasks were given to the man-machine combination in the form of specific translations at predetermined height. Control inputs were introduced on the basis of assumed fixed response characteristics of a human to stimuli such as height deviations, ground plane distance deviations, velocity, and acceleration. True trajectories based on these control inputs were then computed on digital equipment. One interesting analysis concerned the trajectory after a forward leg kick of assumed duration and nature. This may be, it seems, a good starting point for analytical studies of kinesthetic control characteristics by performing inverse analysis, i.e., given a prescribed trajectory, solve for the leg motions necessary to maintain the trajectory.

Although the digital computer approach offers advantages in the form of accuracy and the use of more detailed analytical expressions, the analog approach has the advantage of a human operator. Although his response characteristics differ between real and analog flights he can express judgement concerning the similarities and dissimilarities, desirable and undesirable behavior, especially if he has acquired tethered or free-flight experience. This was the case for two of the three pilots involved in the analog studies.

The actual prototype control stick was incorporated in the simulation. It was mounted on a sheet metal bracket and attached to a slide wire potentiometer whose output was fed to the computer.

In addition to the control stick, the actual SRLD has provisions for kinesthetic shoulder control. The nossle arms are attached to a pivot bearing located behind the head and can be rotated by shoulder movements. This system was not, however, instrumented with the computer. The overall system block diagram is shown in Figure 29. ϑ_{g} = NOZZLE DEFLECTION DUE TO CONTROL STICK ϑ_{g} = NOZZLE DEFLECTION DUE TO STABILITY AUGMENTATION DEVICE

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Figure 27. Stability Augmentation Deflection Limits as a Function of Nozzle Deflection Due to Control Stick



q. = UPPER BODY ATTITUDE, DEGREES
x LATERAL DISPLACEMENT, FT
SCOPE DISPLAY RATIOS:
 I^o SCOPE = I^o ATTITUDE

2" SCOPE 2 20 FT LATERAL DISPLACEMENT

Figure 28. Oscilloscope Display Schematic



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A systematic evaluation of the stability augmentation system was the first phase of the study. The object was to find the effect of frequency and damping on the controlled behavior of the man-machine combination, and if possible, to specify desirable values for design purposes. Twenty-five combinations of frequency and damping were chosen.

Following these stability system tests, the effects of other parameters were studied. These parameters included the hip-spring constant, upper and lower body moments of inertia, nozzle height above the gross center of gravity, and maximum nozzle deflection. The hip spring constant used for initial studies was an experimentally-determined value. It was obtained by suspending a man and measuring the force-deflection relation of his legs for a semi-relaxed condition.

A simplified pilot-rating system was used. This system (shown below) was chosen because of its simplicity and, being a comparative type, would quickly establish trends.

| Letter Rating | Description |
|---------------|----------------|
| A | Very Good |
| В | Good |
| C | Fair |
| D | Poor |
| F | Uncontrollable |

B. RESULTS AND DISCUSSION

First attempts to control the system were not successful, but as the study progressed and the pilots acquired learning time, their ability to control the system improved. The results of the first stability system tests are shown in Figure 30. Note that pilot A was given a velocity display. That is, the horizontal displacement of the oscilloscope image was proportional to lateral velocity rather than displacement. The velocity display was introduced to determine the effects of display response on the pilots' level of performance. Reference 1 shows that derivative information can have significant effects on pilot performance. This did not seem to be true for these tests and display effects were not pursued further. Figure 30c is a combination of Figures 30a and 30b. It separates the ratings into C-D and D-F groups. These results were not particularly gratifying since 39 of the 50 ratings were

Figure 30. Results of Stability Augmentation System Tests



(B) PILOT A (VELOCITY DISPLAY)

(A) PILOT B

| 0 L L 0 0 1 0 L L 0 0 0 1 0 L 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 L 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | 2 |
|--|---|
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | L |
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either D or F. It was concluded that:

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- 1. Some damping in the lateral stability system is desirable.
- 2. The stability augmentation system might be of secondary importance.

Following these stability system tests, probes were made to determine which, if any, of the other parameters had significant effects on the controlled behavior. During these probes it was noted that the scope image maintained a hovering attitude if the pilot kept his hands off the control stick when the computer was turned on. When he attempted maneuvers the system soon became uncontrollable. These extremes — uncontrollable by pilot and satisfactory hovering with no control inputs — pointed to excessive control moments. With excessive control, spurious pilot-induced control moments result in rapidly occuring uncontrollable motions.

A series of runs were then made to determine the effects of maximum available control by changing maximum nozzle deflection and nozzle height above the gross center of gravity. Results are shown in Figure 31. Although most of the ratings are uncontrollable or nearly so, the difference, as noted by the pilots, between the 3, 6, and 9 degree deflections were definitely in favor of the 3 and 6 degree maximum nozzle deflections.

On the basis of these tests the SRLD hardware was modified by lowering the nozzle gimbal point from 3.75 inches to 2 inches above the gross center of gravity. The maximum nozzle deflections are easily adjusted on the SRLD. The 6 degree maximum deflection will be used in the first series of flight tests. This will give a maximum rolling moment of

TRmax = 280 lb

$$M_{\max} = \frac{T_R \max}{2} \times \frac{6^{\circ}}{57.3} \times \frac{2}{12}$$

= 2.44 ft-lbs

The maximum value used in Reference 2 is 12.5 foot-pounds. This rolling moment is obtained from maximum differential thrust of 10 pounds at a 15-inch moment arm. It is felt that the nature of analysis, i.e., digital vs pilot-controlled analog, account for this large difference. The roll-lateral translation motions are coupled, and pilots observing the oscilloscope display rated the total motion.

| NOZZLE HEIGHT | MAXIMUM NO | ZZLE DEFLECT | ION , DEGREES |
|-----------------------|------------|--------------|---------------|
| ABOVE GROSS C.G., IN. | 3 | 6 | 9 |
| 2 | Ŧ | F | F |
| 3.75 | F | F ' | F |
| a 5 | F | F | F |
| 8 | f | 0 | F |
| tt | D | F | D |
| 15 | D- | ŕ | D- |
| | PILOT A | PILOT B | PILOT A |



Figure 31. Effect of Maximum Nozzle Deflection and Moment Arm on Pilot Ratings. Inertial Exploratory Tests on Stability Augmentation System

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The maximum stick deflection remained constant as the maximum nozzle deflection was varied. Thus, as the nozzle deflection was reduced from 9 degrees, its design value, to 6 and 3 degrees, the stick deflection-

nozzle deflection gradient, as measured by $\frac{\Theta_{K} \max}{\delta_{N} \max}$, increased by factors of 1.33 and 3.00 respectively. The effect of a constant deflection gradient

for various nozzle deflections was not evaluated.

After those tests it was discovered that an increased value of hipspring constant and moment of inertia of the lower body had significant effects on the system behavior. Figure 32a shows the effect of increased hip spring constant and Figure 32b shows the effect of raising the legs. Comparison of the results in Figure 31 and 32 shows that the hip spring constant has a primary influence on the controlled lateral behavior. It is probably one of the least accurately known parameters.

Short exploratory studies were also made to study the effects of mass and inertia characteristics on the controlled lateral behavior. There were slight but noticeable effects. More detailed studies may be in order at later stages of development.

During the course of the studies concerned with nozzle heights above the gross center of gravity, there appeared an interesting phenomenon which may be related to kinesthetic control behavior. Consider the two-segment body shown in Figure 33a. If a force is suddenly applied at some point above the gross center of gravity, the line joining the upper and lower centers of gravity will translate and rotate to the left. If the line of action of the force passes above the upper body e.g. it will excite the bending mode as shown in Figure 33b. If the line of action passes below the upper body e.g. it will excite the bending mode as shown in Figure 33c. At one time when the nozzle gimbal height was alightly above the gross e.g., this latter phenomenon was observed. For rapid control inputs the oscilloscope image, which represented upper body attitude, began initial angular motions in a direction opposite that desired by the pilot. This phenomenon was also observed on captive flight tests with nitrogen rigs.

As mentioned earlier the pilots became more proficient as the studies progressed. The direction of angular movement of the display image appeared to be the primary stimulus. When the pilots learned to lead this angular movement properly with the control stick, they could maintain the upper body attitude within reasonable limits. Lateral displacement seemed HIP SPRING CONSTANT = 50 FT-LB/RAD.

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| NOZZLE HEIGHT | NOZZLE | DEFLECT | ION, DEG. |
|------------------------|---------|---------|-----------|
| ABOVE GROSS C.G. , IN. | 3 | 6 | 9 |
| 2 | A | В | В |
| 3.75 | C | C | C |
| 5 | C+ | D | C |
| 8 | С | D | C- |
| 11 | C- | D | D |
| 15 | D- | D- | 0- |
| | PILOT A | PILOT B | PILOT A |

(a)

HIP SPRING CONSTANT = 50 FT - LB/RAD. INERTIA OF LOWER BODY CORRESPONDING TO LEGS UP CONDITION

| NOZZLE HEIGHT | NOZZLE | DEFLECTIO | N, DEG. |
|-----------------------|---------|-----------|---------|
| ABOVE GROSS C.G., IN. | 3 | 6 | 9 |
| 2 | A | A | A |
| 3.75 | , D+ | C | C+ |
| 5 | C-ir | C- | C |
| 8 | Ø | D | D |
| | D- | 0- | F |
| 15 | F | F | F |
| | PILOT B | PILOT A | PILOT B |

(b)

Figure 32. Effect of Increased Hip Constant and Inertian of Lower Legs on Pilot Ratings



Figure 33. Illustration of Body Bending Mode Excitation

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of secondary importance as a response stimulus. The pilots became more critical in their judgement as they became more proficient and began annotating plus (+) and minus (-) signs to the letter ratings. They repeated runs often and felt that with practice they could do better for the test runs in the D-F category.

C. CONCLUSIONS

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From the results of the analog computer studies of the pilot-controlled lateral behavior of the SRLD the following conclusions can be made:

- 1. If stability augmentation is incorporated some damping should be present and low frequencies avoided. The overall studies do not show that stability augmentation is absolutely necessary.
- 2. The hip-spring constant has a primary influence on the system dynamics. High values are most desirable. Since it is a combined human-factor and physiological parameter its value is not accurately known.
- 3. Mass and inertia characteristics have noticeable effects on controlled behavior and further studies may prove valuable at a later date.
- 4. Control moments reduced from original design values resulted in highly improved handling characteristics.
- 5. The two-segment model exhibits some basic dynamic: characteristics that make it suitable for analysis of SRLD configurations. Continued analysis may yield information valuable for kinesthetic control analysis.

D. RECOMMENDATIONS

Based on the overall test results it was recommended that the nozzle gimbal height of 2 inches above the gross c.g. be adopted along with 6 degree maximum nozzle deflection. These numbers would result in improved controlled lateral behavior characteristics.

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Participation of Human Factors Personnel during Phase I, consisted chiefly in obtaining anthropometric data on the flight-test operator, proposing different pessible control configurations, monitoring design of the SRLD feasibility model, providing body-mass data for REAC analog computer studies, and preparing flight plans for the SRLD Captive Flight-Test Program.

A. ANTHROPOMETRIC DATA

The anthropometric data presented in Table 2 were used in design of prototype equipment. Fitting of the fiberglass corset by means of a plastercast of the body was monitored by human factors and medical specialists. Emphasis was placed on supporting weight of the propellant-loaded SRLD device about the hips where severe injury is least likely to occur in a hard landing.

B. CONFIGURATIONS TO BE CONSIDERED

A hand controller-arm restraint design, which is relatively insensitive to acceleration forces, was proposed. Because of increased complexity over the existing design, the proposed concept was not incorporated in early test hardware. Unless simulator data and/or actual flight test indicate a need for reducing acceleration effects at the controller, this will not be incorporated during the program.

The following control system configurations were proposed for consideration in future design, or as specific alternatives to be included in the test program.

1. Pitch and roll control allocated to one hand, and throttle and yaw to the other. This would minimize the possibility of cross-coupling to be anticipated in a three-axis controller.

2. Kinesthetic control for pitch and roll, with a tiller or steering bar control for yaw. Yaw appears to be the control function most difficult to achieve by kinesthetic means and requires separate control. Steering and throttle control may then become a one-hand operation, freeing the other hand for other tasks.

| | | TABLE | 2 | | |
|------------------------|--------|------------|------------------------|----------|-----------|
| | ANTHRO | POMETRIC | DATA RECORD | - | |
| Name: Wendell Moore | | Age: 4 | 12 | Date: 22 | Aug 60 |
| | P4I | ercentile | | 11-1 | ercentile |
| Weight | 147.5 | 24 | Shoulder Breadth | 18.0 | 55 |
| Stature | 69.5 | 57 | Chest Breadth | 11.5 | 25 |
| Cervical Height | 59.5 | 57 | Waist Breadth | 10.5 | 45 |
| Shoulder Height | 58.2 | <u>L</u> . | Hip Breadth | 13.3 | 55 |
| Suprasternale Height | 56.5 | 53 | Chest Depth | 9.7 | 80 |
| Waist Height | 43.5 | 80 | Waist Depth | 9.7 | 96 |
| Crotch Height | 32.5 | 43 | Neck Circumference | 14.8 | 9 |
| Sitting Height | ı | ۱ | Shoulder Circumference | 43.5 | 23 |
| Buttock-Leg Length | 41.8 | 33 | . Chest Circumference | 33.3 | 15 |
| Span | 69.5 | 33 | Waist Circumference | 32.5 | 60 |
| Arm Reach | 33.5 | 25 | Buttock Circumference | I | . • |
| Elbuw to Elbow Breadth | 17.0 | 45 | Vertical Trunk | 62.0 | 16 |
| Hip Breadth | 13.7 | 40 | Circumierence | | |
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3. Operator head motion for two or three-axis control. For example, control linkages could be fastened to head hand or helmet, with forward head movement resulting in pitch forward to translate forward; the head moved to the right, would result in roll right, and translate right; rotating the head to the right or left would result in yaw.

One hand must necessarily be occupied with throttle control. It therefore seems probable that two-axis head control might be most desirable, with yaw and throttle control to be assigned to one hand as described rhove. Advantages of this system would include optimized control-response corrolation, freedom of one hand for other tasks, and possible simplification of the control linkages.

C. BODY-MASS DATA

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The Human Factors Section prepared body-mass distribution, center of gravity and spring rate data for use by the flight technology group in analog simulation studies.

After review of available literature, it was aecided to use a regression equation developed by Barter, (see Reference 3) in determination of mass distribution data.

Center of gravity location in the separate body segments was derived by determining the over-all c.g. location of the test pilot experimentally, comparing it with average over-all c.g. location as determined by Dempster (see Reference 4) and using the resulting ratio to modify the body-segment c.g. locations as determined in the same reference.

Spring rate data for the human body, in the region of the abdomen and hip joint, was derived experimentally. The test pilot was suspended in a mockup of the SRLD, and his upper body immobilized by fore, aft, and side tethers fastened at the waist. The force required to deflect the lower extremities in increments of five degrees was measured using a spring balance and large protractor. Measurements were taken in four directions -- fore and kit, and left and right. Spring rates were then calculated. Body segment weights used in the calculations were determined from the Barter regression equalicas. Observed and calculated data are presented in Table 3.

D. PREPARATION OF CAPTIVE FLIGHT TEST MANS

Flight-test plans were formula of with assistance from human-factors personnel in order to provide, as much as possible, for optimal conditions and sequences in learning to operate the SRLD, and to allow for these effects in evaluating alternative configuration.

TABLE 3

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OBSERVED AND CALCULATED ANTHROPOMETRIC DATA

| Parameters | Value | () ! | Remarks | | , | | | |
|---|------------------|--|--|--------------------------------|-----------------------------|--|--|--|
| Over-all length (supine), incl | a 70.5 | } - | | | | | | |
| Top of head to hip socket. in | ch 29.5 | | | | | | | |
| Knee to ankle inch | 16 75 | | | | | | | |
| | | • • • | | | | | | |
| | 144.0 | ; n | | | • | | | |
| Upper body segment, 1b | 97.0 | Determitions pe | ined using re r Barter* | gressic | on equa- | | | |
| Lower extremities., lb | 47.0 | Determinitions pe | ined using re r Barter* | gressio | on equa- | | | |
| Center of Gravity - Over-all inch | , 28.6 | From to | p of head | | | | | |
| Upper tody segment | 17.8 | From to center o centage Dempst | op of head (de of gravity loc of segment l er **) | etermin ations (ength p | ed using Rs 2 per- er | | | |
| Thigh, inch | 9.0 | From h | ip joint** | | | | | |
| Leg, inch | 7.4 | From k | From knee joint** | | | | | |
| Foot, inch | 1.5 | From a | From ankle (estimated) | | | | | |
| JANY JANA SP | RING RAT | e data | | | | | | |
| | Tension Angle | in Pounds. | Normal to L | og at A | n <u>kle</u> | | | |
| | Degree I | eft Right | Average | Fwd | Back | | | |
| | 5 | 1.5 2.5 | 2.0 | 1.5 | 1.5 | | | |
| 1 1 1 1 1 1 1 1 1 | 10 | P.5 4.5 | 4.0 | 8.0 | 3.0 | | | |
| 11 1. 1 1 1 | 15 | 5.0 7.0 | 6.0 | 4.5 | 6.0 | | | |
| 1° NRK ~ TK | | 9.0 9.5 | 9.35 | 5.5 | 7.5 | | | |
| | | | 13,0 | 8,0 10 0 | ¥.5 | | | |
| | <u>JU 1</u> | 0.U 10.U | 10.V | 10.0 | 19.U | | | |
| *Barter, reference 3 **Dempster, reference 4 | | | | | | | | |

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Two theoretical principles of learning were considered: (1) Simpleto-complex sequential progress and (2) whole-part practice.

A simple-to-complex sequence of SRLD tasks was thought be to an optimal plan for progressive skill acquisition by the SRLD flight operator. On a rational basis this was thought to be, perhaps, a progression from a simple hovering task to one requiring complex maneuvering. The flight plan was therefore established in this basis. However, further consideration of SRLD flight requirements has suggested that in actuality the hovering task may be the most difficult, and the plan may require revision on this basis.

The whole-part theory of practice in learning a complex motor skill was applied in recommended training and practice. For example, some combination of whole and part practice is employed and considered most effective in such motor skills as golfing, boxing, swimming, etc. In swimming, "whole" practice is accomplished by attempting the complete motor sequence, such as swimming across the pool. "Part" practice in the training-to-swim procedure is accomplished by practicing only the kick or the breathing rhythm.

The motor skill requirements in flying the SRLD, on a rational basis, would seem to involve such elements as proficiency in throttle, or vertical, control, yawing, pitching and rolling by such movements as those required of the arms, trunk, and legs, balancing and executing "kinesthetic" control for maneuvering. Further considerations are: muscle conditioning to bear the weight of the pack, adaptation to the clothing and required protective equipment, etc.

Several exploratory flights were proposed to provide the operator with such familiarization as might be described as "whole" practice. "Part"-type practice was accomplished and/or recommended as follows:

- 1. REAC analog computer tracking in the lateral and pitch axis.
- 2. REAC analog computer tracking in the vertical axis.
- 3. Adaptation and conditioning to personal equipment and the hip pack by exercises, similar to those required in flight, under dryrun conditions.
- 4. REAC analog computer coordinated control of vertical, pitch, yaw, and roll axes.

F. FLIGHT TEST PLANS

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SRLD captive flight test plans were based on theoretical problems in learning to fly the SRLD, and on the tests and experimental controls necessary to evaluate the different possible SRLD flight control configurations.

Over-all flight test objectives in tethered flight were defined as follows:

- 1. Chiefly, to establish feasibility of control and flying qualities with optimal safety.
- 2. To establish the control configuration on the basis of performance criteria that are most proficiently controlled for free-flight tests.

Feasibility is to be largely established on the basis of general observations and flight operator opinion. The optimal control configuration will be determined on the basis of flight rating charts and quantitative analysis of film records.

The SRLD control system, proposed at this stage of the program, is to be provided with the following possible options to be tested:

- 1. "Kinesthetic" control, where a spherical pivot bearing at a center point to the shoulder harness is free to permit thrust diversion about the shoulders in pitch and roll. Locking is optional. (A pivot in the pitch axis has recently been discussed as unnecessary.)
- 2. "Automatic Roll Stabilization" with a left-hand stick, where linkages in roll actuate nozzles laterally, in pitch longitudinally, and in yaw, differentially in the longitudinal axis. Locking is optional for all axes, or any individual axis. (The automatic stabilization feature has been temporarily abandoned since the original thinking on this option. This was necessary due to the excessive weight that, it was determined, would be required for effective control.)

Table 4 lists the configurations in combinations of the above, and the flight tasks for performance evaluation.

The following order of flights were planned in order to control the biases that would otherwise be incurred from adaptation and learning. This is important, since the performance criteria with each configuration will be compared to select the optimal configuration for free flight tests. (The following Roman Numerals are also referred to in Table 4. I. Hovering Control Tests - Ascend to five feet, maintain straight and steady attitude until timer signal occurs, descend and touch down.

> Test 1 - Configuration A Test 2 - Configuration B Test 3 - Configuration C Test 4 - Configuration D

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II. Lateral Control Tests - Ascend five feet, translate right side to mark, return left to zero position, hover, and let down.

Test 5 - Configuration A Test 6 - Configuration B Test 7 - Configuration C or D*

III. Yaw-Right Control - Ascend to five feet, turn around right 360 degrees, hover, and let down.

Test 8 - Configuration E Test 9 - Configuration C or D*

IV. Yaw-Left Tests - Ascend to five feet, turn around left 360 degrees, hover, and let down.

Test 10 - Configuration E Test 11 - Configuration C or D*

V. Pitch Control Tests - Ascend to five feet, translate forward to mark, hover, and let down.

Test 12 - Configuration E Test 13 - Configuration C or D*

VI. Combined Control - Ascend to five feet, translate forward to mark, turn around right 180 degrees, and translate forward to zero position, hover, and let down.

> Test 14 - Configuration E Test 15 - Configuration C Test 16 - Configuration D

*This decision will be based on preliminary performance criteria in comparison of Tests 3 and 4.

TABLE 4

| | | Flight | | |
|------------------------------|------------------------|----------|------------------|--|
| | Configuration | Plan No. | Flight-Test Task | |
| A | Kizeathatia | Т | Wovening | |
| - - - - - - - - - - - | IN HOUSING | TÎ | Lateral Control | |
| | | ** | | |
| B. | Kinesthetic and Auto- | I | Hovering | |
| | Roll Stabilization | Π | Lateral Control | |
| C. | Manual and Auto-Boll | т | Hovering | |
| Ψ. | Stabilization | π | Lateral Control | |
| | | m | Yawing Right | |
| | | īv | Yawing Left | |
| | | v | Pitch Control | |
| | | VI | Combined Control | |
| D. | Kinesthetic, Manual | T | Hovering | |
| 2. | and Auto-Boll | v | Combined Control | |
| | Stabilization* | | | |
| ٦. | Kinesthetic and Manual | 111 | Yawing Right | |
| ه انتظ | Vaw | 1V | Varing Loft | |
| | A 66 W | v | Ditch Control | |
| | | vī | Combined Control | |
| | | ** | | |

PLANNED SRLD TETHERED FLIGHT TESTS

*To be substituted for Configuration C, depending upon results in the hovering tasks. A free pivot, or kinesthetic control, may be essential in compensating for full center of gravity shift.

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| Test | Same as | Test | Same as |
|------|----------|------------|----------|
| No. | Test No. | <u>No.</u> | Test No. |
| 17 | 16 | 25 | 8 |
| 18 | 15 | 26 | 7 |
| 19 | 14 | 27 | 6 |
| 20 | 13 | - 28 | 5 |
| 21 | 12 | 29 | 4** |
| 22 | 11 | 30 | 3** |
| 23 | 10 | 31 | 2** |
| 24 | 9 | 32 | 1** |

**Propellant duration time measures will be completed during these flights.

Preliminary evaluation criteria were established in the use of a flight rating chart by specialized observers and the flight operator himself, as well as flight analysis of film records following each flight.

Table 5 presents a flight rating chart to be used in the experimental evaluation.

Markings are provided on the flight operator's suit in order to facilitate interpretation and analysis of performance from film records. Figure 34 presents the front, side and rear flight suit markings to be employed.

Photographic records are expected to provide such performance data as follows:

- a. Time to complete maneuvers
- b. Accuracy of maneuvers
- c. Damping rate

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d. Translation rate

e. Ascent-descent rate

f. Interferring body and/or control motions.

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| | | | 11110 | ai i usauut | TABLE 5 | | | | | |
|--------------------------------------|--|--------------------|---|------------------------------|--|-----------------------------------|-------------------------|--|----------------------|--|
| st Dete | | | | . RUCKET LIE (Please chec | it one number f | for each rating) | HAKE | | Test No. | |
| | 1 | 2 | • | 4 | | • | 7 | 80 | a | 10 |
| | Excellent | Good | Satisfactory | Acceptable | Marginal | Ütacceptable | Impossible | Hazardous | Dangerous | Killer |
| ereral ating | Completely Confident | Easy to Control | Mincr Diffi- culties in Control | Difficult to Control | Not much Confidence | Control Extremely Difficult | Cannot be Controlled | Injury Could Result | Operator Was Hurt | Fatal Injury May Result |
| oll-or- ateral ontrol ating | Steady and Controlled | | Oscillations Quickly Cor- rected and Trimmed | | Oscillations Deficult to Control, Caraot Trim | | | Serere Oscil- laticus Carnot Be Controlled | | Oscillations and Direction Camot be Controlled |
| itch or ore-and- it Rating | Steady and Controlled | | Moments Quickly Corrected and Trimmed | | Moments Difficult to Control, Carmot Trim | | | Severe Mo- ments and Oscillations Cannot be Controlled | | Oscillation and Direction Cannot Be Controlled |
| ter Racing | Steady and Controlled | | Spin Oscil- lations Quickly Corrected | | Spin Diffi- cult to Control | | | Spin Rate and Occillations Cannot Be Controlled | | Spin Oucilla- tions and Direction Cannot Be Controlled |
| antrol ross- auting Iting | Uni-Directional and Steady | | Some, But Easy to Con- troi | | Interference Difficult to Control | | | laterierence Cannot Be Controlled | | Sets Up Un- controllable Omni-Direc- tional Inter- farence |
| ransla- 20 Con- ol Hating | Accurate and Precise | | Close and Adequate | | Poor Con- troi | | | Way Off Target | | No Control Winthoever |
| otr Cou- | Easy Posture and Deliberate Morements | | Body Sume- what Tense, But Control Easy | | Disturbing Monsents Induced. Posture Difficult to Control | | | Limbs Flail, Tense, No Control | | No Control Wintsoever |
| artical Matrol | Accurate and Precise Smooth Takeoff and Landing | | Some fluc- tration Easily Controlled | | Difficult to Malacin, Takeoff and Laading Irregular | | | Caunot Be Controlled, Hard Take- off and Landing | | Control Im- possible Takeoff and Landing |



G. SUMMARY

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Human Factors effort during the Phase I program has consisted largely in providing basic body-mass data, flight control analyses, and assisting in the preparation of a tethered-flight test plan. Flight-operator training requirements were also considered as part of the flight test program in order to develop control proficiency.

V. RELIABILITY

During the Phase I period, the reliability effort consisted of monitoring the testing of components for inclusion of reliability and safety objectives and analysis of the past history data on components used on the SRLD that have been utilized on other programs at Bell Aerosystems Company.

The components have been tasted for performance parameters consistent with the SRLD design requirements. As highlighted elsewhere in this report, changes and/or modifications were made on components to meet the design requirements and to enhance the reliability and safety of the system by meeting or exceeding the system requirements. Although these components have successfully achieved the design requirements, only system level testing during Phase II will conclusively establish component safety margins because system failure definition in terms of component tolerances cannot be rigorously established at the component test level. Phase II will demonstrate the level of reliability achieved by the SRLD in tethered and free flights of the system.

Six components utilized on the SRLD have experienced various phases of testing during functional, system checkout, and system flights. These components are as follows:

| 1. | 8060-472001 | Manual Shutoff Valve |
|----|--------------|--|
| 2. | 8060-472004 | Gas Filter |
| 3, | 62-472-088-1 | Check Valve (Modified to 8123-472003) |
| 4. | 8060-472036 | 2-Way Selector Valve (Pressure and Vent Valve, (8123-472015) |
| 5. | 8060-472122 | Relief Valve |
| 6. | 59-472-275-1 | Fiil and Drain Valve (8123-472005) |

Table 6 presents a summary of the background data applicable to the SRLD program on each of these components and includes the computed and lower 90% confidence reliability when based on a 30-second flight of the SRLD.

1. 8060-472-001 - MANUAL SHUT-OFF VALVE

Eighty-six (86) units have been functionally tested and no failures were observed. During 527 hours of system testing, the manual shut-off valve was

TABLE 3

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SUMMARY OF BACKGROUND DATA APPLICABLE TO SRLD PROGRAM

| | | | | | | | | | 1- |
|---------------|-------------|--------------|--------------|--------------|--------------|---------------|--------------|------------|----------|
| | | | | | | | Commute | d 30 sec. | |
| | Func | tional | Syst | tem | | | Reliabi | lity for | · |
| | Test | Phase | Checkout | t Phases | Flight | Phase | SRLD Pr | ogram (3) | |
| | Number | Unit | Component | | Component | | | | |
| Component | of Units | Rejection | Cperating | Observed | Operating | Observed | | Lower 90% | <u> </u> |
| No. | Tested | Rate | Time | Reliability | Time | Reliability | Computed | Confidence | |
| 8060-472001 | 86 | 0 | 527 hr. | 0.9981/hr. | N/A | ı | 0.99998 | 0.99996 | |
| 8060-472004-1 | 38 | 2.6% | 705 hr. | 0.9986/hr. | N/A | I | 0.99999 | 0.99997 | |
| 62-472-088-1 | 243 | 1.2% | 212 hr.(1) | 0.8438/hr. | 8.4 hr. | 1.00 | 0.99864 | 0.99830 | |
| 8060-472036 | 13 | 31.79 | 527 hr. | 0.9931/hr. | N/A | I | 0.99998 | 0.99996 | |
| 8060-472122 | 17 | 0 | 270 hr. | 1.0000/hr. | N/A | ١ | 1.00000 | 0.99993 | |
| 59-472-275-1 | 1614 | 1.3% | 11275 hr.(2) | 0.9999/hr. | 42.1 hr. | 1.00 | 0.99999 | 0,59999 | |
| | | | | | | | | | -T- |
| (1) Two compt | onents used | d during 42; | 3 system che | ckouts avera | ging 2.5 hou | irs of pressu | rization per | checkout. | |
| (2) Ten compo | ments used | during 451 | system chet | ckouts avera | ging 2.5 hou | rs of pressur | ization per | checkout. | |

System level testing during Phase II will conclusively establish component safety margins. System failure definition in terms of component tolerances cannot otherwise be rigorously established.

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fail-free. Serial number 211 and 213 have been tested successfully for the SRLD. Based upon this data, this valve is computed to have a 30-second reliability of 0.99998 or 1 failure per 63,240 flights of the SRLD.

2. 8060-472-004-1 - GAS FILTER

Two discrepancies were experienced during the functional testing of 38 filters. One unit had a slight leakage at 3000 psig. Upon failure analysis, it was found that the teflon back-up ring was out of dimensional tolerance and this unit was returned to the vendor. Leakage at 4000 psig was also observed past the "O" ring on the second unit. However, the failure could not be duplicated, and the unit was successfully retested.

This filter has had extensive experience in a test cell as well as formal and informal PRFT testing. No system failures have been observed in 705 hours of operation.

The SRLD program has accepted filter numbers 205 and 206.

Based upon system data, this gas filter is computed to have a 30-second reliability of 0.99999 or 1 failure in 84,600 flights of the SRLD.

3. 8123-472-003-1 (62-472-088-1) - CHECK VALVE

This valve has had extensive experience in a previous program at Bell Aerosystems Company. Out of the 243 units functionally tested, only three units were rejected for failing the reverse flow requirements and were not acceptable for rework. Twenty-eight (28) units that failed during these tests were subsequently accepted after rework.

During system checkout, the dominant mode of failure experienced by this component was leakage. It was determined that 76 percent of these 38 leakages were caused by acid salt deposits from the oxidizer on the seat and poppet area. Since this oxidizer will not be used in the SRLD system, this mode of failure is considered to be of a much lower magnitude.

When this valve was used in actual flight, no failures were observed. Data from 2492 functional tests cycles, 423 system checkouts, and 101 flights of this component were analyzed and a summary of the results are presented below:

| Observed reliability during flight (150 seconds) | 1.00 |
|---|--------|
| Observed reliability during checkout (1 hour) | 0.8438 |
| Observed unit rejection rate during functional test | 1.2% |

The reliability of this check valve, when based on a 30-second flight, is computed to be 0.99864 or approximately 1 failure in 733 flights of the SRLD.

Serial numbers 1 and 2 have been acceptance-tested for the SRLD program. These values are of the 8123-472-003-1 configuration which makes them compatible with H₂O₂.

4. 8060-472-036 - TWO-WAY SELECTOR VALVE (PRESSURE AND VENT VALVE)

Thirteen (13) units have been functionally tested to date and one failure was observed. This unit failed B/P Note #54, and allowed free flow past the push-pull spool. This unit was sent to rework to eliminate the scored seat at Port "C".

During system testing of this valve, the valve experienced 462 fail-free cycles in 527 hours of operation. Utilizing this system test data, this valve is computed to have a 30-second reliability of 0.99998 or 1 failure per 63,240 flights of the SRLD.

5. 8060-472-122 - RELIEF VALVE

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This new valve has had no failures during the functional testing of seventeen (17) units tested to date.

This relief valve has performed successfully during 270 hours of system testing and when these data are applied to a 30-second flight of the SRLD, the computed reliability would be 100 percent. Since this valve is a safety component to prevent system rupture in the event some impurities are accidentally introduced into the system, this 100 percent flight reliability will continue. This is based on the fact that over-pressurization will be evident prior to flight, therefore, the flight will be aborted and action taken to eliminate the abnormal situation.

6. <u>59-472-275-1</u> — FILL AND DRAIN VALVE (8123-472005)

Data from December 1953 to date has been analyzed on this fill and drain valve. A total of 1614 units have been functionally tested and experienced 101 failures. However, only 21 units were rejected with the balance of the units being accepted after rework.

During system checkout, one failure was observed. A deposit of acid salts on the seat and poppet area had allowed leakage of the oxidizer. Since this oxidizer will not be used in the SRLD system, this type of failure will not exist. No failures were observed when this valve was in flight.

Data from 3283 functional test cycles, 451 system checkouts, and 101 flights of this component were analyzed and a summary of the results are presented below.

| Observed reliability during flight (150 seconds) | 1.40 |
|---|---------|
| Observed reliability during checkout (1 hour) | 0.99978 |
| Observed unit rejection rate during functional test | 1.3% |

The reliability of this fill and drain valve during system checkout, when based on a 30-second flight, is computed to be 0.99996 or approximately 1 failure in 25,000 flights of the SRLD.

During Phase I, the gas generator was tested for performance, reliability, and safety. One hundred and one tests were conducted on the gas generator with no performance degradation in 3070 seconds of operation. Forformance parameters have displayed a consistent ±1% repeatability and no safety havards were evident. Since the gas generator is a direct outgrowth of the present gas generators used on other programs, it is evident that the high degree of reliability necessary for this man-rated system has been achieved.

The throttle control valves and rocket nozzles have been modified to meet the design requirements at the component test level. Due to the time delay in the modification of the throttle control valve, the scheduled 500 cycle reliability test was not accomplished in Phase I. Any "unreliable factors" in these components are a function of mechanical tolerances in the successful performance of their operation. The design of these components has been orientated towards minimizing critical tolerances to enhance reliability. Any additional features that become evident in subsequent flight during Phase II will be incorporated.

Since the proposed regulator did not meet the design requirements, a modified Grove 94% Mitey-Mite regulator was chosen as a substitute. This regulator was tested to obtain regulation and flow characteristics of the regulator under various cycle and flow tests and to establish a confidence level of reliability. Although the regulator had dropped 10 psi below the initial setting after 250 cycles, this is not considered significant and this regulator is adequate for SRLD use. Based upon the data of this test, there is 90 percent confidence that the regulator would not have more than one failure in 110 flights of the SRLD. The best estimate, which is less pessimistic, has a reliability of no more than one failure in 175 flights. The ANSC25HX415-21 compressed gas cylinder is an ICC-approved item and past history throughout the industry has indicated a high level of reliability.

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Cycle, proof, and burst tests were conducted on the H2O2 tank assembly for performance parameters and for reliability and safety factors. After 2000 successful cycles, the tanks were tested for a burst pressure. At 1150 psi, a crack developed at the lower left hand weld area and testing was terminated. This 2.2 relief valve-to-burst factor is considered to be a sufficient safety margin for the SRLD design.

The gages and hi-pressure fill valve have met the design requirements of the SRLD. Bell Aerosystems Company does not have detailed experience data on these components, although they are accepted by industry for their performance parameters and reliability.

Based upon past experience and Phase I testing, it is felt that the SRLD can achieve the high degree of reliability necessary for this man-rated system. The actual level of reliability that can be demonstrated will be a function of the flights made during Phase II.

VI. REFERENCES

- 1. McKee, John W., "Single Degree of Freedom Simulator Investigation Of Summing Display -- Instrument Signals On Man-Machine Control." NASA TN D-148, December 1959
- 2. "<u>Feasibility Study of a Small Rocket Lift Device</u>" Aerojet-General Corporation, Report No. 1751, February 1960.

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- 3. Barter, J. T., "<u>Estimation Of the Mass Of Body Segments</u>", Aero Medical Laboratory, WADC TR 57-260, April 1957.
- 4. Dempster, W. T., "<u>Space Requirements Of The Seated Operator</u>", University of Michigan under Contract to Aero Medical Laboratory, WADC TR 55-159, July 1955.

Appendix I. Compatibility of Polyvinyl Chloride Rubber with 90% Hydrogen Peroxide

A. GENERAL

The following results are applicable for both vinyl rubbers submitted for test. The materials are:

1. Rubatex R-310V

2. Ensolite, U. S. Rubbor

B. MATERIAL COMPATIBILITY

The vinyl rubbers were immersed in 90% hydrogen percuide with no immediate reaction upon contact. After a 5-minute retention period, several bubbles were slowly forming on the surface of the materials. This process proceeded for 24 hours and then the samples were removed from the peroxide. At no time was there noted any vigorous evolution of gas.

The vinyl rubbers retained most of their resiliency, but suffered a marked decrease in tensile strength. They swelled to approximately 150% of their original volume. The color was bleached from tan to light tan, approaching white.

C. SHOCK SENSITIVITY

The apparatus used to determine the following data was an Olin-Mathieson Impact Sensitivity Tester. The information reported are average values of numerous drop tests.

| | Rubbers Subjected to: | Impact Sensitivity Inch-Ounces | Comments |
|----|--|--------------------------------------|--|
| 1. | Virgin . | 6992 | Very stable to shock. |
| 2. | Overnight soak in 90% H2O2, squeezed dry, test run. | 5520 | Quite stable to shock. |
| 3. | Overnight soak in 90% H2O2, soaked in water for 10 min., squeezed dry, test run. | 6256 | Very stable to shock. |
| 4. | Overnight soak in 90% H ₂ O ₂ , soaked in water for 10 min., air dried for 24 hrs., test run. | 4600 | Not as stable to shock as above. |
| 5. | Same as (4), except dried @ 122°F for 24 hrs,, test run | 3220 • | Approaching the lower limits of shock stability. |
| 6. | TMT | 2000 | As a comparison, quite |

C. SHOCK SENSITIVITY (Cont'd)

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| | Rubbers Subjected to: | Impact Sensitivity Inch-Cunces | Comments |
|----|-----------------------|--------------------------------------|------------------------|
| 7. | RDX | 1340 | Quite shock sensitive. |
| 8. | Lead Azide | 720 | Very shock sensitive. |

At no time were explosions encountered during the above tests, but definite discoloration of the materials warrants that they be classified as shock sensitive for that particular situation.

Appendix II. SRLD System Distilled Water Flow Tests

ROCKET LABORATORY PRELIMINARY TEST REPORT

| Test Engineer | <u> </u> | <u> 81100</u> | | فالتناكب ويحبيهم | | Tea | rt Fac | ility | <u>W-1</u> | |
|---------------|----------|---------------|-------|------------------|--------------|---|--------|-------|------------|----------|
| Date | | | \ | - | ۱ ـــــــ | - | Work | Order | 687 | 76-000 |
| Test Item SN | _1_ | Test | Ю., | 10-91 | , | · · · · · · · · · · · · · · · · · · · | Test | Item | SRL | <u>D</u> |
| | • | | | | | | | • | | |
| ·. | | | | | | | Sheet | 1 | of | |

TEST:

SRLD System Distilled Water Flow Tests.

PURPOSE:

d.

To evaluate the nitrogen pressurisation and propellant tank systems in regard to available nitrogen and usable propellants.

REMARKS :

See attached sheets.

DATA RECORDED ON: Speedomax

and the second second

Test No. 1

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- 1. The tanks were filled with distilled H₂O up to the point of tangency between cylinder portions and domes using approximately 30 psig pressure. The time required to fill the tanks was 7 min/45 sec.
- 2. The N2 bottle was charged to 2000 psig. Leaks were noted at the inlet port of the shutoff valve and at the "O" ring under the schrader valve. The tests were run without scaling these leaks.
- 3. The 94 X dome pressure was vented.
- 4. The pressure and vent valve was placed in the pressurize position.
- 5. The N₂ shutoff valve was opened.
- 6. The 94 X dome was adjusted to provide a propellant tank static pressure of 450 psig. The nitrogen system was recharged to 2100 psig.
- 7. The system was flowed until the first indication of gas at the outlet was noted. The hand valve (throttle valve not available), was shut off as soon as possible. The propellant tank pressure dropped to 430 psig during the run. Thirty pounds of water were discharged during the run. The source pressure prior to the run was 1900 psig. After the run the source pressure was 950 psig. The maximum flow was 1.40 lbs/sec of H₂O.
- β . The tanks wore vented by means of the pressure and vent value.
- 9. The tanks were drained and found to contain a residual of 1.5 pounds of H2O.

Test No. 2

- 1. The tanks were filled with distilled H₂O up to the point of tangency between cylinder portions and domes using approximately 30 psig pressure.
- 2. The No bottle was charged to 2100 psig.
- 3. The pressure and vent valve was placed in the pressurize position.
- 4. The N₂ shutoff valve was opened at the rate of approximately 90° (full open) in one second and the tank pressure rose in a gradual manner with no overshoot noted on the tank pressure gage. The tank pressure was 450 psig.

- 5. The system was flowed at full open until the first indication of gas at the outlet. The hand valve was shut off as soon as possible. Thirtythree and a quarter pounds of H₂O were discharged. The source pressure prior to the run was 1900 psig. After the run the source pressure was 700 psig. The maximum flow was 1.92 pounds of H₂O/sec., and was maintained for a total of 17.2 seconds.
- 6. The tanks were vented by means of the pressure and vent valve.
- 7. The tank contained no residual water.

Test No. 3

- 1. The tanks were filled with distilled H₂O up to a level of one inch above the dome tangency point, using approximately 30 psig.
- 2. The N2 bottle was charged to 2150 psig.
- 3. The pressure and vent valve was placed in the pressurize position.
- 4. The N₂ shutoff value was opened at the rate of approximately 90° (full open) in one second and the tank pressure rose in a gradual manner with no overshoot noted on the tank pressure gage. The tank pressure was 150 psig.
- 5. The system was flowed at full open, until the first indication of gas at the outlet. The hand valve was shut off as soon as possible. The propellant tank pressure dropped to 410 psig during the run. Thirtyfour and a quarter pounds of H20 were discharged. The source pressure prior to the run was 2000 psig. After the run the source pressure was 750 psig. The gage downstroam of the orifice was recording a pressure of 170 psig. The maximum flow was 1.89 lbs/sec and was maintained for 17.4 seconds.
- 6. The tanks were vented by means of the pressure and vent valve.
- 7. The tanks contained no residual water.

Test No. 4

- 1. The tanks were filled with distilled water up to a level of one inch above the dome tangency point using approximately 30 psig.
- 2. The N2 bottlo was charged to 2100 psig.
- 3. The pressure and vent valve was placed in the "vent" position.

- 4. The N2 shutoff valve was opened.
- 5. The pressure and vent valve was put 'n the pressurize position. The propellant tank N2 pressure rose in a gradual manner (slow rise), with no overshoot noted on the tank pressure gage to a pressure of 450 psig. However, the regulator did not hold this pressure but allowed the tank pressure to very slowly creep up to 510 psig. The source pressure dropped to 1875 psig.
- 6. The pressure and vent valve was placed in the vent position. A little H2O vapor was noticed leaving the vent line.
- 7. The pressure and vent valve was placed in the pressurize position. The propellant tank N₂ pressure was 450 psig. The source pressure dropped to 1775 psig.

The pressure and vent valve was placed in the vent position. A little H2O vapor was noticed leaving the vent line.

- 8. The pressure and vent valve was placed in the pressurize position and the system was flowed until about 22% of the original tank water was still in the tanks. At this point the shutoff valve was closed. Twenty-six and three quarter pounds of water were discharged. The source pressure prior to the water flow was 1775 psig. The source pressure after the water flow was 900 psig.
- 9. The tanks were vented by using the pressure and vent valve.
- 10. The system was repressurized with the remaining source pressure of 900 psig. There was no rise in static regulated tank pressure noted because the source pressure and the tank pressure were both equal to 290 psig.
- 11. The hand value was opened and the entire system allowed to deplete itself of water and nitrogen. The propellant tanks contained 34 pounds of water when they were filled for this run.

Test No. 5

- 1. The N2 bottle was charged to 2100 psig.
- 2. The propellant tanks were filled with distilled water up to a level of one inch above the dome tangency point using approximately 30 psig.
- 3. The pressure and vent valve was placed in the pressurize position.
- 4. The No shutoff valve was opened.

5. The dome pressure of the 94 X regulator was raised until the relief valve opened. This pressure was 600 psig. The N2 shutoff valve was shut off.

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6. The N_2 shutoff value was opened and the relief value was opened a few more times. The opening pressure remained at 600 psig. This value was subsequently reset so that for 3 cycling operations it opened at 530 psig, and reseated at 465-480 psig.

| | | | | | | | | | | | | Sh | eet 6 | of 7 |
|-------------------------------------|--------|--------|--------|----------|-----|----------|--|---------|------|------|------|------|------------|---------------------|
| Dynamic Tank Pressure | 430 | l | סניז | 1 | 1 | 8 | Length of Bun at Maximum Flow in Seconds | ſ | 17.2 | 17.4 | · | ŀ | I * | |
| Tank Pressure | 450 | 150 | 1450 | SIC | 450 | 290 | | | | | | · | | mmary . |
| Residual H2O (Lbs.) | 1-1/2 | C | 0 | 0 | t | I | Maximum Actual Flow Lbs/Sec | 1.40 | 1.92 | 1.89 | 0.40 | ı | • | low Tests - Data Su |
| Total Flow H2O (Lbs.) | 31-1/2 | 33-1/4 | 34-1/1 | 34 | 3. | 1 | ressuro nstream of Drifice | s. B | ł | 170 | t | 1 | ĩ | SRLD Systen Water F |
| 12 Bottle Frassure After Flow | 950 | 700 | 750 | 006 | | F | μ, go | | | | | | | Table III-1. |
| M2 Bottle Charge | 2100 | 0012 | 2150 | 2100 | 1 | 1 | N2 Bcttle Charge Fressura For Flow | 2100 | 1900 | 2000 | 1875 | 1775 | 290 | |
| -17 17 | | t e | V (~ | <u>م</u> | t 1 | <u>ل</u> | Test. No. | -1 | 2 | m | 4 | 4 | ţ | |





Appendix III. Nitrogen Pressure Regulator

ROCKET LABORATORY PRELIMINARY TEST REPORT

| Sheet | 1 | of | 4 | |
|-------|---|----|---|--|
|-------|---|----|---|--|

| Test Item SN | Test No. <u>81232-1-3</u> | Test Item | SRLD |
|---------------|---------------------------|---------------|-----------|
| Date | November 24, 1960 | Work Order | 6876-000 |
| Test Engineer | J. LaSpisa | Test Facility | Cell D-6A |

TEST:

Flowing of the Grove 94X Mity-Mite Regulator, reworked to RLO 8123-005, per LTR 60-R-33.

PURPOSE:

To obtain regulation and flow characteristics of the regulator under various cycle and flow tests and to establish a confidence level of reliability.

PRCCEDURE:

The regulator was installed in a test system as represented in the following diagram: Hiese 0-1000 psig



PROCEDURE: (Cont'd)

Sheet 2 of 4

The regulator was tested in the following sequence:

- 1. The regulator was adjusted to 457 psig pressure in a dead ended condition.
- 2. A seat leakage test was conducted for 30 minutes at an injet pressure of 2150 psig and the outlet pressure dead ended in a 2.79 in³ volume. A Hiese gage was used to monitor outlet pressure and gas temperature was monitored with thermocouples.
- 3. The seat leakage was repeated at an inlet pressure of 850 psig.
- 4. The regulator was cycled 250 times by opening and closing hand valve #3 to flow 42 scfm at each cycle. At each 25 cycles, the following parameters were recorded.
 - a. Source pressure, regulated pressure and tempsratures at dead ended conditions.
 - b. Source pressure, regulated pressure and temperatures while flowing h_2 sofm of N_2 gas.
 - c. Source pressure, regulated pressure and temperatures while flowing 62 sc.m of No gas.
 - d. Source pressure, regulated pressure and temperatures at dead ended conditions.

At no time during the 250 cycle test, was the source pressure in the 415 in³ tank, allowed to decay below 800 psig.

5. Steps numbers 2 and 3 were repeated.

DATA AND RESULTS:

1.2.2.1

Leak test at 2150 psig.

| Elapsed Time (min) | Source Pressure (psig) | Regulator Pressure (psig) | Temperature (°F) |
|-----------------------|---------------------------|------------------------------|---------------------|
| 0 | 2150 | 456 | 57° |
| 15 | 2150 | 456 | 57° |
| 30 | 2150 | 456 | 57° |

Leak test at 850 psig.

| Elapsed Time (min) | Source Pressure (psig) | Regulator Pressure | Temperature (°F) |
|-----------------------|---------------------------|--------------------|---------------------|
| 0 | 850 | 459 | 64 ° |
| 15 | 850 | 460 | 68° |
| 30 | 850 | 460 | 68 ° |

| ding. | HE | | 5 | 57 | 33 | 58 | tto | 8 | 50 | 6.1 | 1,5 | 47 |
|------------------|-------------------|------|------|------|------------|------------|--------------|------------|--------------|--------------|--------------|--------------|
| о° Н | <u>عا</u> | | 64 | 59 | 5 2 | 53 | 56 | 65 | 61 | 53 | 8 | 8 |
| Reg. Press. | Flow | | 1,58 | 1462 | 1459 | 455 | 450 | 1452 | L53 | li52 | 1,50 | 150 |
| Source Press. | No Li | | 2271 | 1250 | 1330 | 1220 | 1285 | 1380 | 1 390 | 0221 | 1260 | 1320 |
| Reg. Press. | a Science H | ` | 6141 | 455 | 1450 | 9777 | ০শশ | धाग | 91110 | enti | 대 | 115 |
| Source Press. | | | 0071 | 5711 | 1270 | 1150 | 1200 | 1275 | 1320 | 1200 | 1200 | 01/21 |
| Ê. | B | | 57 | 55 | 3 | 4 9 | म | ъ С | ጜ | 1 <u>4</u> 8 | 4 . 8 | 147 |
| 191 | - Iai | | 61 | 57 | 64 | 8 | 59 | 86 | % | 86 | 8 | 38 · |
| Reg. Press. | scfm | | गगग | 1417 | धाग | 014 | 1131 | 137 | 864 | 137 | 1 <u>3</u> 3 | 1,33 |
| Source Fress. | ac or | | 1360 | 1120 | 1230 | 0211 | 57.LL | 1280 | 1285 | 1150 | 0011 | 5111 |
| CH H | Ш | | 57 | 8 | ъ З | 켯 | 1 <u>4</u> 8 | 53 | 47 | म | 37 | 38 |
| E . | H | | 68 | 68 | 58 | 58 | 덨 | 59 | 63 | 55 | | Ъ |
| Press | scfa t | | 1417 | 1,52 | 1,1,8 | 1111 | 1,38 | 2111 | ELLI | 다 | 1 ,38 | 954 |
| Source Press. | scfm | | 1800 | 1620 | 1700 | 1650 | 1600 | 1700 | 1750 | 1680 | 1700 | 1680 |
| ġ. | ŧ | 70 | 67 | 69 | 62 | 59 | 5 <u>7</u> | 2 8 | Ş | £ | ୟ | R |
| 96 1 | 비리 | 20 | 8 | 69 | 62 | 57 | Ŗ | 8 | 63 | 28 28 | 51 | у |
| Reg. Press. | NON | 1,60 | 1t57 | 1;60 | 1,58 | 453 | 8141 | 1,50 | ŢŹŊ | 450 | 1448 | 877 |
| Jource Press. | NO IE | 2150 | 2110 | 1900 | 2100 | 086I | 1900 | 2010 | 2090 | 2010 | 2090 | 2040 |
| Cycle No. | | Ы | 25 | S | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 |
| | | | | | | | | | 90 | | | |

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250 Cycle Test

Sheet 3 of 4

Leak Test at 2150 psig.

| Elapsed Time (min) | Source Pressure (psig) | Regulator Pressure (psig) | Temperature (°F) |
|-----------------------|---------------------------|------------------------------|---------------------|
| 0 | 2150 | 451 | 70° |
| 15 | 2150 | 455 | 71° |
| 30 | 21.50 | 457 | 73° |

Leak Test at 850 psig.

| Elapsed Time (min) | Source Pressure (psig) | Regulator Pressure (psig) | Temperature (°F) |
|-----------------------|---------------------------|------------------------------|---------------------|
| 0 | 850 | 457 | 68° |
| 15 | 850 | 461 | 72 ° |
| 30 | 850 | 463 | 72 ° |

SUMMARY AND CONCLUSIONS:

Tank capacity of the 415 in³ source tank was sufficient to run 25 cycles plus one cycle into instruments. The tank was repressurized after every 25 cycles.

Regulated pressure dropped about 10 psi during flow at 42 scfm as compared to dead ended pressure. It dropped another 5 psi while flowing 62 scfm. At the end of 250 cycles, the regulated pressure had dropped to 450 psig, which is 10 psi lower than the setting at the first cycle. This pressure is the minimum setting requested in the L.T.R.. The lowest pressure recorded during flow, was 433 psig at 625 scfm. This drop, of 17 psi from the minimum 450 psig setting; was considered tolerable by the Small Recket Lift Device Engineers.

Gas temperature, at the outlet of the regulator dropped an average 10°F during flow at each recorded cycle.

The summary of the data, shows that this regulator should be satisfactory for use in the Small Rocket Lift Device.

Appendix IV. Accumulated Reliability Test Data

ROCKET LABORATORY PRELIMINARY TEST REPORT

Sheet _____ of ____2

| Test Item SN | 1 Test No. LD_1 | thru LD | Test Item | SRLD |
|---------------|------------------|-------------------------|-------------|------------|
| Date | October 14, 1960 | و المراجع و المراجع الم | Work Order | 2228-025 |
| Test Engineer | F. A. Urbaniak | Te | st Facility | <u>W-1</u> |

TEST:

Cas Generator

PURPOSE:

Conditioning of catalyst bed.

REMARKS:

A REAL PROPERTY AND A REAL PROPERTY OF

Test unit ran seven seconds of a scheduled 30-second run. Test was discontinued because the nozzles shifted, causing the steam to miss the exhaust ducts; consequently, filling the test cell with steam. Nozzle shift was due to the mounting bracket not being stiff enough. This is being corrected.

Examination of the data disclosed that the unit did not reach stability.

DATA RECORDED ON: Speedomax

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CELL W-1

Sheet 2 of 2

| At = . | 7040 in^2 | | Tes | t No. I | D- 1 | to LD | | | | | |
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| RNP | psig | | 268 | | | | | | | | |
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| GGP | psig | ļ | 278 . | | | | | | | | |
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ROCKET LABORATORY PRELIMINARY TEST REPORT

Sheet 1 of 3

| Test Item SN | 1 Test No. LD-2 thru LD-9 | Test Item | SKLD |
|---------------|---------------------------|---------------|------------|
| Date | October 17, 1960 | Work Order | 2228-025 |
| Test Engineer | F. A. Urbeniak | Test Facility | <u>W-1</u> |

TEST: .

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Gay Generator

PURPOSE :

Catalyst bed conditioning and initial gas generator assembly reliability runs.

REMARKS :

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1.D-2 and -3 were made to condition the catalyst bed and determine the proper tank pressure to set before the runs.

LD-4 through -9 were a series of 30-second runs maintaining a gas generator pressure of 285 psig.

DATA RECORDED ON: Speedomax

and each state of the provident of the state

| | | | CELL W | <u>-1</u> | Sheet | 2 | of <u>3</u> | | | |
|----------------|------------------|------------|--------|---------------|-------|----------|-------------|--------|-------|--|
| | T ดฮ | st No. I | I.D- 2 | _ to ID | - 6 | | | | | |
| _[,] |) . 2 | T.D- | -3 | L.D- | 4 | LD- | 5 | L'D | -6 | |
| 18 | 3.5 | 28. | 5 | 30.(| 2 | 30.5 | 7 | 30 |).2 | |
| <u> </u> | .5 | 54. | ,0 | 84.0 | 3 | 114.7 | 7 | 144 | 144.9 | |
| i _c | 18.0 | Static | 28.0 | Static | 29.5 | Static | 30.2 | Static | 29.7 | |
| | -264 | <u>∔</u> ′ | 260 | | 2777 | | 201 | | 260 | |
| | | <u> </u> | 207 | ├─── ┤ | | <u>├</u> | 674 | | 209 | |
| | 264 | | 270 | | 278 | } | 273 | | 269 | |
| | 273 | | 277 | | 284 | | 282 | | 277 | |
| _ | 350 | | 369 | | 382 | | 380 | | 378 | |
| | 369 | 477 | 389 | 496 | 402 | 495 | 404 | 489 | 399 | |

| RNP | psig | | 264 | <u>`</u> | 270 | | 278 | | 273 | | 269 |
|-----------------|----------------|--------------|---------|---------------------------------------|---------------------------------------|---|--------|---------------------------------------|---------------|------------------------|---|
| ngp | psig | | 273 | | 277 | | 284 | | 282 | | 277 |
| FLP | psig | | 350 | · | 369 | | 382 | | 380 | | 378 |
| LP | psig | 452 | 369 | 477 | 389 | 496 | 402 | 495 | 404 | 489 | 399 |
| TP | psig | 456 | 418 | 478 | 439 | 501 | 459 | 498 | 454 | 490 | 450 |
| _∆Þ | psi. | | 30.9 | | 32.6 | | 33.6 | | 32.6 | | 31.8 |
| W . | lb/sec | | 2,15 | | 221 | · · · · · | 2.24 | | 2.21 | | 2,19 |
| LNT | Oħ. | | 1560 | <u> </u> | 1371 | | 1382 | | 1370 | | 1381 |
| RNT | OF | | 1.382 | | 1391 | | 1341 | | 1380 | | 1376 |
| OGT | o _F | | prratic | | 1124 | | 1216 | | 1289 | ····· | 1230 |
| FLT | | | | | | | | | | | |
| ·PFT | | | | | | | | | | | +++++++++++++++++++++++++++++++++++++++ |
| EXT | or | | | | | | | - | | | |
| BT | or | | | | | | | | | | |
| Ts ₁ | | | off sea | 10 | 12.53 | | 1242 | | 1260 | | 1287 |
| Ts ₂ | oĥ | | 1149 | | 1100 | | 1097 . | | 1123 | | 1160 |
| Тяз | o _F | | off sca | 1.0 | 1 ²¹)?. | | 1304 | | 1309 | | 1303 |
| <u>C+</u> | fl/sec | | | | | | 2960 | | 2959 | ******** | 2940 |
| Tr. | 16 | | | · · · · · · · · · · · · · · · · · · · | | | 273.9 | ** *** ** ************** | 270.1 | 1.01.6 6.0 1.00 | 265.9 |
| Тер | \$ <u>6</u> 6 | | | · ················ | ····· | ***** &= ***** ******************************* | 122.3 | | 122.2 | | 121.4 |
| Peorr | (b/ase | | | | | | 2.35 | 144 m 1834 - 194 m 1944 m 1944 | 2.32 | | 2,31 |
| Fean | | ····· •···· | · • • | | | | 282.0 | | 284,2 | | 280,9 |
| To Aba | Corr | •• •• •••• • | | · · · · · · · · · · · · · · · · · · · | · · · · · · · · · · · · · · · · · · · | ···· | 306:5 | · · · · · · · · · · · · · · · · · · · | 303.5 | • • • • • • | jo o,õ |
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TEST NO.

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DURATION SOC EDURATION SOC TIME OF DATA

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Static

CELL W-1

Press.

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Sheet <u>3</u> of <u>3</u>

| At = ,7 | 040 in ² | | Tes | t No. I | .D-7 | to ID | - 9 | | | | |
|---------------------------------------|-----------------------------------|------------|---------|---|----------|---------------------------------------|-------------|----------------|---------------------------------------|--------------------|-----------------------------|
| TEST NO | • | Ľ.D-7 | | I.D 8 | | I.D- 9 | | LD-, | | I,D_ | |
| DURATION Sec | | 30.0 | | 30.2 | | .30.0 | | | | | |
| 2DURATT | CN sec | 1. | 74.9 | 20 | 5.1 | 235 | .1 | | | ļ | |
| TIME CE | DATA | Static | 29.5 | Static | 29.7 | Static | 29.5 | <u>Static</u> | | Static | |
| TATD | | | 070 | | 075 | | 6776 | | · | | |
| LINF | psig | | 213 | | 275 | | 210 | | | + | |
| RNP | | | 070 | | 077 | | 077 | | | + | |
| | bark | | 213 | | 210 | | _2[[| | | | |
| IRP | DSIF | | 281 | | 282 | | 285 | | | + | |
| | P6 | | 6. U.J. | | 202 | | 607 | | | + | |
| FLP | psig | | 382 | | 384 | | 387 | | | 1 | |
| · · · · · · · · · · · · · · · · · · · | | | | | | | | | | 1 | |
| LP | psig | 494 | 402 | 497 | 403 | 503 | 408 | | | | |
| | | | | | | | | | | | |
| TP | psig | 495 | 455 | 504 | 460 | 507 | 463 | | | | · |
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| Δ^{p} | psi | | 32.7 | | 33.5 | | 33.7 | | | | |
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| W | Tolec | | 2.22 | | 2.24 | | 2.25 | | · · · · · · · · · · · · · · · · · · · | + | |
| TINT | | <u> </u> | 1070 | - | 1922 | | 7 25% | | | + | <u> </u> |
| DIAT | | - | 17:12 | <u>├</u> • | | · · · · · · · · · · · · · · · · · · · | 0001 | | | - - | <u></u> ┥╼╍╴╼╍╼╼┥ |
| RNT | | | 1268 | | 1267 | | 7 3 81 | | | -+ | ┟╼╍╍╼┥ |
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| COT | | h | 1390 | <u>↓</u> * | 1179 | ····· | 1392 | | | + | <u>├</u> |
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| FLT | OF | | | · | | | | | <u> </u> | - | |
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| PFT | oF | | | | | | | | | | |
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| TV0 | 0 | | | | | | | | | | ļ |
| BL | P | | | | | | | | | | |
| Ter | | | 1257 | | 1277 | | 1236 | | | + | |
| .91 | <u> </u> | <u> </u> | | <u> </u> | | | | <u>├──</u> -── | <u> </u> | + | h |
| T82 | | <u> </u> | 11.85 | ╉╍──└── | 1171 | | 1166 | | | + | |
| <u></u> | | | | | | | | | <u> </u> → | 1 | <u> </u> |
| T83 | or | | 1291 | | 1284 | | 1270 | | | | |
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| C* | ft/sec | | 2941 | | 2940 | | 2937 | | | | |
| | | | | | 000 - | | 070 - | | | + | |
| <u>.</u> | 16 | ļ | 209.7 | <u> </u> | 272.0 | | 272.9 | | | | |
| T | | | 121 E | | 107 1 | | 101 0 | | | · <u> </u> | |
| _L S P | 800 | ł | 127.02 | <u> </u> | + | | TUT 3 | <u> </u> | | -{ | <u> </u> |
| Waann | lb/sec | <u> </u> | 2.33 | ┢──── | 2.34 | | 2.34 | | | | |
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| Fcorr | 16 | | 282.8 | | 28/1.2 | | 283.7 | | | 1 | |
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| Pc Abs | ļ | 302.0 | | 303.5 | | 303.0 | | | | | |
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ROCKET LABORATORY PRELIMINARY TEST REPORT

Sheet: 1 of 2

| Test Item SN | 1 Test No. LD-10 | thru LD- 12 | Test Item | SRLD |
|---------------|------------------|-------------|-------------|------------|
| Date | October 18, 1960 | | Work Order | 2228-025 |
| Test Engineer | F. A. Urbaniak | Те | st Facility | <u>W-1</u> |

TEST:

Gas Generator

PURPOSE:

Reliability Testing of Gas Generator Assembly

REMARKS:

Runs LD-10 and 11 were made maintaining a gas generator pressure of 285 psig. From Run LD-12 on, chamber pressure will be defined by Nozzle Pressure.

All three runs were smooth and were of 30-second duration each.

DATA RECORDED ON: Speedomax
Sheet 2 of 2

| At = . | 7040 in ² | | Tes | t No. [| D- 10 | to ID | -12 | | | | |
|-----------|--|---|------------------|---------------------------------------|----------------|--------------|---------------------|----------|----------|----------------|---|
| TEST N | 10. | NºL- | 010 | I,D_ | 11 | LD- | 12 | LD- | | [,D | |
| DURATI | "∩N <u>soc</u> | 30 | •5 | 29 | .9 | 30. | 7 | | | | |
| E DUR A'I | "]CN see | 26 | 5.6 | 29 | 5.5 | 32(| 5.2 | L | | · | |
| TINE (| TF DATA | Static | 30.0 | Static | 29.4 | Static | 30.2 | Static | | Statio | |
| TIT | | | 000 | | | | | | + | | |
| LINP | psig | | 272 | | 273 | | 279 | | | | |
| | | | 070 | | | | 070 | | | | |
| | [10].[; | | 212 | | <u> </u> | | 219 | | | | |
| 400 | psig | | 279 | | 2/9 | ****** | 286 | | | | |
| | | | | | | | | | | | |
| FLP | psig | | 383 | · · · · · · · · · · · · · · · · · · · | 385 | | 395 | | | | |
| | | | | | | | | | | | |
| LP | psig | 458 | 1103 | 499 | 404 | 514 | 117 | | | | |
| | | | 1.20 | 707 | 1./- | | 1 022 | | | | |
| 1. | parg | 202 | 420 | 505 | 401. | <u>51(</u> | 411 | | | | |
| ΛP | nst | <u> </u> | 32-8 | <u> </u> | 32-B | | 3/1-7 | | · | | |
| <u> </u> | P01 | | 52.00 | <u> </u> | | | يل قاري سيل ماري | | -d | {i | · |
| W | 16/500 | <u> </u> | 2.22 | | 2.22 | | 2.26 | | | | |
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| LNT | ন্ত | | 1350 | | 1352 | | 13/19 | | | | |
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| RAT. | | <u></u> | 1356 | | 1358 | | 1356 | | | | |
| | 07 | | 12260 | <u> </u> | 3265 | | 22/1 | | | | |
| GIFC | | | 7705 | | -1302 | | 1.300 | | | | |
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| 113 | or | | 1261 | | 1260 | | 1270 | | | | · |
| | Ph Inna | · | 1001 | <u> </u> | 201.75 | | 2010 | | | | |
| | 10/ 800 | | <u> 62,33.</u> | + | - <u>e 200</u> | <u> </u> | <u> </u> | + | | | |
| | 1b | · • • • • • • • • • • • • • • • • • • • | 268.7 | | 270.1 | <u> </u> | 275.3 | | | 1 | |
| | and the second | | | | | <u> </u> | | | | | |
| Lin. | | | 151.0 | | 121.7 | | 151.0 | | | | |
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| 1 BU WH | 107 SHO | | ,,,?;,? ? | | | | J. 2+32 | .] | | <u> </u> | |
| 1 Corre | · · · · 16 | · · | 280.05 | h | | | 1579573 | | <u> </u> | +- · - | |
|) and Ott | | | 1.26.14 | 1 | }• '- '- ' | ··· ·· · · · | 1 | | | | |
| Pe At | crr | | 341 5 | | 301.0 | | 301.5 | | | | |
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Sheet 1 of 2

| Test Iter SN | 1 Test No. 10- 13 thru 10- 17 | ' Test Item | SRID |
|---------------|-------------------------------|---------------|------------|
| Date | October 18, 1960 | Work Ordar | 2228-025 |
| lest Engineer | H. M. Graham, 2nd Shirt | Test Facility | <u>W-1</u> |

TEST:

30-second full thrust firings on the gas government

FURPOSE:

To determine the reliability of the gas generator assembly.

REMARKS:

No noticeable drop in nozzle prossure was recorded.

TATA PECCRDED ON: Speedomax

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CELL W-1 Sheet 2 of 2

| At = . | 7040 m ² | | Ten | t No. F | J)=] 3 | to D | | | , | | |
|--|---------------------|---|-------------|---------------------------------------|------------------|---------------------------------------|---------------------------------------|--------------------|--------------|-----------|--|
| TEST N | (` | <u>[]</u> |) | -01 | <u>)h</u> | <u> </u> | <u></u> | <u> </u> | 1.6 | 1'1) | - 17 |
| DURATT | | <u>ر</u> | 0•2 82 1 | 30 | 2 | 29. | . <u>8</u> 5-1. | 30 |),6 | 30 | <u>, ()</u> |
| TIME C | F DATA | j Static | 20.4 | Static | 22.7 | Static | 29.3 | <u>u</u> Static | 30.1 | Stable | 29.5 |
| | | · • • • • • • • • • • • • • • • • • • • | | ····· | | | e sind genetic | | | 1. WOMANY | n ten ten ten ten ten ten ten ten ten te |
| INP | psig | | 279 | | 282 | | 286 | | 285 | | 5 86 |
| 12102 | | | 091 | | | | 0.077 | | 285 | | 0.01 |
| | | | <u> </u> | | -201 | | _201 | | - 202 | | 7.02 |
| qub | <u>, psig</u> | | 288 | | 291 | | 294 | | 202 | | 29'1 |
| FLP | psig | | 396 | | 103 | | 1.08 | | 1:07 | | 1:08 |
| | F | ······· | | | 402 | | | | | | |
| LP | psig | 515 | 421 | 522 | 426 | 533 | 432 | 529 | 428 | 533 | 429 |
| TP | puig | 522 | 178 | 520 | 1.80 | 536 | 1.88 | 535 | L 87 | 536 | 1.88 |
| | | | | | | | | | | | |
| <u>P</u> | psi | ····· | 34.1 | | 35.0 | | 35.7 | | 35.7 | | 35.7 |
| W | lb/sec | | 2.26 | · | 2.28 | | 2.31 | | 2.31 | | 2.30 |
| | | | | · · · · · · · · · · · · · · · · · · · | | | | | | | |
| LNT | - TO | | 1348 | | 1354 | | 1352 | | 1352 | | 1367 |
| RNT | | | 1358 | | 1365 | | 1360 | | 1361 | | 1358 |
| | | | | | | | | | | | |
| GGT | | | 1384 | | 1359 | | 1355 | | 1358 | | 1355 |
| FLT | ন্ত | | | | | | | | | | |
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| PFT | • | | | | | | | | | | |
| EXT | -To | | | | | | | | | | |
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| BT | | | | | | | | | | | |
| Ts1 | o _F | | 1267 | | 1268 | | 1265 | | 1266 | | 1275 |
| Tr- | Or | | 1000 | | 1021 | | 1000 | | 1011 | | 7000 |
| <u>152</u> | - r | | 1666 | | 12,34 | | 1200 | | 7571 | | 1555 |
| Ts3 | 0 _F | | 1276 | | 1277 | | 1291 | | 1278 | | 1270 |
| C* | ft/200 | | 2959 | | 2958 | | 2050 | | 2011 | | 2062 |
| | 10/360 | | | | 2/20 | | 6757 | | <u>671+4</u> | | |
| F | <u>].b</u> | | 276.2 | | 278.5 | | 282.3 | | 280. | 2 | 281.4 |
| Tan | sec | | 122.2 | | 122.2 | | 122.2 | | 121. | | 122.3 |
| ······································ | ، | | | | | · · · · · · · · · · · · · · · · · · · | | | | · | |
| -Weorr | 16/800 | | 2.31 | | 2.31 | · | 2.32 | | 2.32 | | 2.31 |
| Feore | 7.6 | | 282.0 | | 281.6 | | 283.2 | • | 282. | 8 | 282.3 |
| | 0 | | 100 1 | | 57.57 | | 200 0 | | 2/14 | | 207 6 |
| 1-10-4pe | uory | | <u> </u> | | <u>(/,,, '</u> ` | | 202.2 | | <u></u> | • | 201-5 |
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Sheet 1 of 2

| SRLD | Test Itom | thru LD- 22 | <u>.1.8</u> | <u>110 -</u> | No. | Tont | 1 | t Itom 58 | Test |
|------------|--------------|-------------|-------------|--------------|------------|---------------|------|-----------|------|
| 2228-025 | Work Order | | | .960 | <u>, 1</u> | obor <u>D</u> | Octo | Date | |
| <u>W-1</u> | est Facility | Тө | | <u>k</u> | ารเรื่อ | 4. Urb | | Engineer | ไอระ |

TEST :

Gas Generator

PURFOSE:

Reliability testing of gas generator assembly.

REMARKS :

And the summary services

These runs were of 30 seconds each. All were smooth and a preliminary look at the data indicates that the values are in the varue expected.

On Run LD-22 the noise level at approximately the location at the pilot's head was checked by a meter to be 132 db.

DATEA RECORDED ON: Speedomax

CELL W-1

のなるが、1997年19月2日まではなる。日本市場になるはなどはないないである。 1997年19月2日まではないでは、1997年19月2日は、1997年19月2日は、1997年19月2日は、1997年19月2日は、1997年19月2日は、1997年19月1日は、1997年19月1日は、1997年19月1日

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Sheet 2 of 2

| At = .7 | 70/10 1n ² | | Tos | t No. I | <u>n- 18</u> | to II |)- 22 | | | | |
|----------|-----------------------|----------|---------|-----------|---------------------------------------|---------------|---------|--------------|---------------------------------------|---------|---------------|
| TEST NO | ` | L.I |)- 18 | I.D- | 19 | LD- | 20 | 1 ,D- | 21 | T,D. | - 22 |
| DURATIC | ' <u>N</u> sec | 30 | •5 | 29 | ? | 29. | 2 | 29. |) | 29.4 | |
| 2:DUFATI | CN SOC | 50 | 7.5 | 537 | •2 | 567 | •1 | 597 | 0 | 626. | 4 |
| TIME CI | * DA ^m A | Static | 30.0 | Static | 29.2 | Static | 29.4 | Static | 29.4 | Static | 28.2 |
| | | | | | | | | | | | |
| LNP | psig | | 285 | | 288 | | 288 | | 286 | | 288 |
| | | | | | | | | | · | | |
| RNP | psig | | 285 | | 288 | | 289 | | 286 | | 288 |
| | | | | | | | | | | | |
| TIOP | psig | | 292 | | 295 | | 297 | | 294 | | 295 |
| ET D | mate | { | 1.09 | | 150 | | 1.51 | | 110 | | 1 |
| I. 101 | hore | | 400 | | 410 | | 444 | | <u>цто</u> | | 412 |
| T 2 | | 500 | 1.00 | 637 | 1.25 | 210 | 1.27 | 621. | 1.20 | 21.0 | 1.94 |
| <u></u> | bark | 267 | 449 | 221_ | 452 | 240 | 421 | 224 | 432 | 240 | 450 |
| 72 | nete | 527 | hal | <u> </u> | 1.01. | <u>- टा.२</u> | 1.02 | 526 | 1.00 | 21.5 | 1.00 |
| <u> </u> | | 221 | 474 | 24. | 474 | 245 | 472 | 220 | 490 | 241 | 490 |
| AP. | 081 | 1 | 25 5 | | 36.0 | | 36 0 | | 26 1 | | 25 0 |
| <u> </u> | | | 2202 | | | | 2007 | | <u> </u> | | 2207 |
| W | lb/sec | | 2,30 | | 2.32 | | 2.35 | | 2.32 | | 2.32 |
| <u>}</u> | | <u> </u> | | | | | | | | | <u></u> |
| LNT | OF. | | 1364 | | 13/6 | h | 1353 | | 1353 | | 1355 |
| | | | | | | | | | and the second | | |
| RNT | OF | | 1356 | | 1355 | | 1350 | | 1356 | | 1372 |
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| GOT | °F. | | 1364 | | 1364 | | 1371 | | 1379 | | 1400 |
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| PFT | | | | | | | | | | | |
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| EXT | | | | | | | | | · · · · · · · · · · · · · · · · · · · | | • |
| | 017 | | | | · · · · · · · · · · · · · · · · · · · | | | | | | |
| <u> </u> | - T | <u></u> | | | | | | | | | |
| TEI | OT | | 1320 | | 1266 | | 1267 | | 1057 | | 1020 |
| <u> </u> | | · | 1,720 | ······ | 1200 | | 1501 | | 1621 | | 12.39 |
| T82 | OF | <u> </u> | 1209 | | 1212 | | 1230 | | 1221 | ┝╼╼╼──┤ | 121.1 |
| h | | <u>†</u> | | | | | <u></u> | | | | HALF PROPERTY |
| T83 | o _F | | 1260 | | 1256 | h | 1266 | | 1261 | | 1271 |
| | | | | | | | | | | | |
| C* | ft/sec | | 2957 | | 2961 | | 2928 | | 29/11 | | 2961 |
| | | | | | | | | | | | |
| F | 16 | ļ | 280.9 | | 283.7 | | 284.2 | | 281,8 | | 283.7 |
| <u> </u> | | | 100 1 | | - | | 104 - | | | | |
| Isp | 880 | | T55•T | | T55°3 | | 150*2 | | 121.5 | | 122.3 |
| W | 16/800 | | 0 27 | | 0.90 | | 0.00 | | 0.00 | | 0 07 |
| - " corr | 10/360 | | C • 2 T | | 2.26 | | 2023 | | 2,32 | | 6134 |
| Foorn | 1b | <u>+</u> | 281_8 | | 283.7 | | 282.2 | | 281 R | | 282 A |
| | | <u> </u> | | | | | | | -040 | | LULOU |
| Pc Abs | Corr | | 301.0 | | 303.0 | | 301.5 | | 301.0 | ······ | 302.0 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 1 | | 1 | | | | | | | | | |

Sheet 1 of 2

| Test Item SN | 1 Test No. LD- 23 thru LD- 27 | . Test Item | SRLD |
|---------------|-------------------------------|---------------|------------|
| Date | October 19, 1960 | Work Order | 2228-025 |
| Test Engineer | H. M. Graham | Test Facility | <u>W-1</u> |

TEST

Contraction of the second

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Gas Generator

PURPOSE:

Reliability testing of the Gas Generator Assembly.

REMARKS :

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All runs smooth and normal.

30-second full thrust firings.

DATA RECORDED ON: Speedomax

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Sheet 2 of 2

| At = .? | 040 j.n ^{c.} |) 11 100-10.3/14000000 pt* 9 | Tes | t No. I | D- 23 | to II |)_ 27 | National Contractory | aning webser | 1 | |
|-----------------|-----------------------|---------------------------------------|------------|----------|------------------|----------|------------|----------------------|--------------|----------|-------------|
| TEST NO | N | <u>[]]</u> |)- 23 | I,D- | . 24 | LD- | 25 | | 26 | 1,1) | - <u>27</u> |
| TURATUCE STURIE | CN 800 | | <u>6 6</u> | <u> </u> | <u>*[</u> K 2 | <u> </u> | <u>6</u> 0 | | 0 | 29 | 2 |
| TIME OF | DATA | Static | 29.6 | Statio | 29.2 | Static | 29.3 | Static | 29.3 | Statio | 29.0 |
| Y 10 | | | 0.07 | | 0.00 | | 0.90 | | 0.02 | | |
| LINP | psig | | 200 | | 200 | | 207 | | 205 | | 202 |
| RNP | psig | | 286 | | 286 | | 286 | | 285 | | 283 |
| GOP | psig | | 293 | | 294 | | 293 | | 292 | | 289 |
| FLP | psig | | 1月0 | | 410 | | 41.0 | | 410 | | 404 |
| LP | psig | 535 | 431 | 534 | 434 | 537 | 434 | 535 | 432 | 530 | 1,29 |
| TP | psig | 539 | 489 | 541 | 491 | 538 | 489 | 538 | 189 | 533 | 182 |
| ΔÞ | psi | | 35.2 | | 36.0 | | 35.6 | | 35.9 | | 34.9 |
| W | lb/sec | | 2,29 | ······ | 2.32 | | 2.30 | | 2.32 | | 2.28 |
| LNT | , OF | | 1355 | ····· | 1350 | | 1353 | | 1353 | | 13/17 |
| RNT | OF | | 1350 | | 1361 | | 1356 | | 1317 | | .735). |
| 007 | O _F | | 1376 | | 1377 | | 1373 | | 11.62 | | 1 2 27 |
| | ^ | | | | | | | | 4,420 | | |
| PDI | OF | | | | | | | | · | | |
| | F | | | | | | | | | | |
| | Op | | | | | | | | | | |
| | | | | | | | | | | | |
| 151 | -F | | T5.15 | ····· | 1200 | | 1270 | | 1277 | <u> </u> | 1261 |
| TS2 | olt | | 1219 | | 1224 | | 1229 | | 1218 | | 1226 |
| Tag | Oľt. | | 1256 | | 1267 | | 1274 | | 1251 | | 1262 |
| C* | ft/sec | | 2980 | | 2941 | | 2972 | | 2931 | | 2958 |
| F | <u>1b</u> | | 281.8 | | 281.8 | | 282.3 | | 280.9 | | 278.5 |
| Įsp | 880 | | 123,1 | | 121,5 | | 122.7 | | 121.1 | | 122.1 |
| Wcolr | lb/sec | | 2.29 | | 2.32 | | 2.30 | | 2.32 | | 2.30 |
| Fcorr | 16 | | 281.8 | • | 281.8 | | 282.3 | | 280.9 | <u> </u> | 281.4 |
| Pc Aba | Corr | · · · · · · · · · · · · · · · · · · · | 301.0 | | 301.0 | | 301.5 | | 300.0 | | 300-5 |
| | | | | | | | | | | | |
| | | | | | 104 | | · | | | | |

and a the second second second straining of expression reads a APP/APP was were at reaching to the

Sheet' 1 of 3

| Test Item SN | 1 Test No. LD- 28 thru LD- 33 Test Item | SRLD |
|---------------|---|----------|
| Date | October 20, 1960 Work Order | 2228-025 |
| Test Engineer | F. A. Urbaniak Test Facility | W-1 |

TEST :

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Gas Generator

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS :

These runs were for 30 seconds each. There was no noticeable change in performance.

The noise level between the nozzle exits was checked on run LD-28 to be 133.5 db.

DATA RECORDED ON: Speedomax

105

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| | | | | | CIELL W | -1 | | Sheet | 2 | of | 3 |
|-----------------------|---------------------|---------------------------------------|---------|---------|---------|---------------|-------|--------------|------------|-----|-------------|
| At = .7 | 040 m ² | | Тоя | t No. I | n- 28 | to IJ |)- 33 | | | | . |
| TEST NO | e e | [.] | 0- 28 | LD- | - 22 | LD- | 30 | I.D- | 3] | T,D | - 32 |
| | N 800 | <u></u> | 3 | 30 | | 30, |] | 29 | <u>9</u> 7 | 29 | ,7 |
| TTNE OF | <u>DAIPA</u> | Static | 129.8 | 03 | 29.6 | COD Shatic | 29.6 | 89 Statio | 20.2 | 92 | 5 <u>.2</u> |
| | | | | | | 00000.0 | | DURULU | <u> </u> | | |
| LNP | psig | | 285 | | 286 | | 285 | | 285 | | 293 |
| RNP | psig | · | 287 | | 287 | | 286 | | 286 | | 294 |
| GGP | psig | | 294 | | 294 | | 292 | | 292 | { | 307 |
| FLP | psig | | 511 | | 112 | | 210 | | דבין | | 1,21, |
| LP | psig | 537 | 432 | 540 | 435 | 539 | 435 | 536 | 434 | 540 | 447 |
| TP | psig | 539 | 190 | 542 | 500 | 540 | 488 | 5111 | 490 | 542 | 506 |
| ₽ | · psi | | 36.1 | | 35.9 | | 35.9 | | 35.6 | | 38.0 |
| W | 16/800 | | 2,32 | | 2,32 | | 2.32 | | 2:30 | | 2.37 |
| LNT | ਾਜੂਹ | | 1347 | <u></u> | 1348 | | 1344 | | 1338 | | 1346 |
| RNT | OF | · | 1356 | | 1347 | | 1350 | | 1311 | · | 13/1 |
| GOT | - OF | `· | 1364 | | 1352 | | 1351 | | 1351 | | 1354 |
| FLT | 0 7 | | | | | | | | | | |
| P#T | 0 _Ř | | | | | | | | | | |
| EXT | OF | | | | | | | | | | |
| 79 | | | | | | | | | | | |
| "ៃទ | oF | | 1303 | | 12111 | | 12/2 | | 1250 | | 1251 |
| "i's2 | ন্ত | | 1238 | | 1223 | | 1225 | | 1231 | | 1226 |
| 183 | o _F | | 1275 | | 1254 | | 1254 | | 1242 | | 1246 |
| C* | ft/sec | | 2911. | | 2916 | | 2936 | | 2962 | | 2951 |
| 7 | <u>1</u> b | | 281.8 | | 282.3 | | 281.4 | | 281.1 | | 288.8 |
| lsp | 5 9 C | · · · · · · · · · · · · · · · · · · · | 121.5 | | 121.7 | | 121.3 | | 122.3 | | 121.9 |
| Woorr | lb/sec | | 2.32 | | 2.31 | | 2.32 | | 2.30 | | 2.32 |
| Foorr | ŢP | | 281.4 | | 281.4 | | 281.4 | | 280.9 | | 282,3 |
| ^{ri} c Abs (| Corr | ······· | 300.5 | | 300.5 | | 300.5 | | 300.0 | | 301.5 |
| | | <u> </u> | | | | | + | | | | |

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| At = .7 | inin in ² | | Tos | t No. I | .D- 28 | to J.D | - 33 | | | | |
|-------------------|--|-----------|---|--|----------|----------|---|-------------|--------|-----------|---|
| TEST NO | \ • | IJ |)- 33 | LD- | | LD- | ÷ ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; | I.D, | | 1,1) | |
| <u>PURATT</u> | M 800 | 2 | 9•7 | ······································ | : | | ***** | | 0 | | |
| LUCATI MINE OI | (N BOC | Statio | 5/1.9 | Stort O | | Cherth a | | 114 - A.4 - | | | · |
| 11,10,00 | DATA | Dref 01 0 | 6706 | .) 64 64 6 | | Statig | | STATIC | | Static | |
| LNP | paig | | 286 | | | | | | | | |
| | | | · • • • • • • • • • • • • • • • • • • • | | • | | | | | | |
| RNP | psig | | 287 | | | | | | | | |
| dab | TRIP | | 202 | | | | | | | | |
| | Port | | 295 | | · | | | | | | |
| Fl.P - | psig | | 413 | | | | | | | | |
| | | File | 1.02 | | | | | | | | |
| UP | ps1g | 539 | 400 | | | | | | | · · · · · | |
| TP | psig | 542 | 493 | | | | | | | | |
| | | | | | | | | | | | |
| _ <u>_</u> _P | psi | | 35.8 | | | | | | _ | | |
| w | | | 2 21 | | | | | | | | |
| | | | 2021 | | | | | | | | |
| LNT | OF | | 1340 | | | | | | | | |
| | | | | | | | | | | | |
| RNT | OF | | 1347 | | | | | | | | |
| TOO | | h | 1361 | | | | | | | | |
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| FLT | oF | | | | | | | | | | |
| DIM | | } | | L | | | | | | | · |
| | | <u>}</u> | | | | | | | · ···· | | |
| EXT | ok | <u></u> | | | | | | | | | |
| 7.00 | | | | | | | | | | | |
| | ······································ | <u> </u> | | | | | | | | | |
| T81 | | <u> </u> | 1238 | | | | | | | | |
| | | | | | | | | | | | |
| Ts ₂ | OF | | 1217 | | | | | | | | |
| 17 813 | OF | ┨╌──── | 1212 | | | | | | | | |
| <u> </u> | | | | | | | | | | | |
| C* | ft/sec | ļ | 2959 | | | | | | | | |
| | | | 0800 | | | | | | | | |
| <u> </u> | 10 | · | 2025 | | | | | | ;! | | |
| Isp | 580 | | 122.2 | | | | | | | | |
| | | | | | | | | | | | |
| "corr | 10/ 300 | | 2.30 | <u> </u> | | | | | | | |
| Foorr | 16 | <u>∱</u> | 280.9 | <u>+</u> | | | | | | | |
| | · · · · · · · · · · · · · · · · · · · | | | · | [| | | | | | |
| Po Aba | Corr | | 1300.0 | | } | | <i>,</i> | | | | |
| } | 1) (1971) (1) — 1971) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) | ·{ | } | <u> </u> | } | | | | | | |
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| Sheet | l | of | 2 |
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| Test | t Item SN | 1 Test No. LD- 34 thru LD- | 38 Test Item | SRLD |
|------|-----------|----------------------------|---------------|------------|
| | Date | October 20, 1960 | Work Order | 2228-025 |
| Tast | Engineer | H. M.Graham | Test Facility | <u>W-1</u> |

TEST :

Gas Generator

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS:

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Setup tank pressure for all runs was 535 psig. No noticeable drop in nozzle pressures occurred during this five (30-sec) run meries.

DATA RECORDED ON: Speedomax

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Sheet _ 2 of _ 2

| _At. = .7 | r040 | | Tos | t No. 1 | 1.D- 314 | to II | o_ 38 | | | | |
|---------------------|------------|--------------|------------------|----------|----------------|-----------------------|----------|----------|--------|---------------|-------------|
| TEST M |) • | Ţ.J | <u>)- 34</u> | T.D- | 35 | LD- | 36 | LD- | . 37 | T.D. | - 38 |
| DURATIC SUURATIC | N SOC | 29 | | 29, | 2 | 29, | 8 | 30. |] | 3 |),0 |
| TIME OF | F DATEA | 90 Static | 28.0 | | 201 | 10///1 1 54 54 5 6 | 0 | 1074 | 1 20.6 | | |
| | | | 20.07 | JORDEO | £7.4 | 010010 | - 27.2 | Scacic | 27.0 | <u>Statio</u> | <u> </u> |
| LNP | psig | | 282 | | 283 | | 284 | | 283 | | 284 |
| | | | | | | | | | | | |
| RNP | psig | | 282 | | 283 | | 285 | | 284 | | 284 |
| nop | paig | | 290 | | 286 | | 292 | | 201 | | 293 |
| | | | | | | | | | | | |
| FLP | paig | | 407 | | 408 | | 100 | | 109 | | 409 |
| LP | paig | 531 | 429 | 534 | 430 | 535 | 432 | 535 | 131 | | 132 |
| | | | | ····· | | | | | | | |
| TP | psig | 532 | 483 | 539 | 490 | 537 | 487 | 536 | 488 | | <u> 188</u> |
| AP | nai | | 31.7 | | 35.2 | | 35.6 | | 31.7 | | 35.5 |
| <u></u> | po1 | | 2401 | | 2200 | | 2210 | <u> </u> | 2401 | | 2/9/ |
| W | lb/sec | | 2.28 | | 2.29 | | 2.30 | | 2.28 | | 2.30 |
| TNT | | | 7011 | ļ | 1.050 | | | | | | |
| | | | 1.344 | | 1.350 | | 1358 | | 1347 | | 1356 |
| RNT | OF | | 1349 | | 1342 | | 1354 | | 1338 | | 1347 |
| | | | | | | | | | | | |
| GOT | F | | 1358 | <u> </u> | 1364 | | 1365 | | 1354 | | 1348 |
| FLT | | | . <u> </u> | | <u> </u> | | <u> </u> | | | | |
| | | | | | | | | | 1 | | |
| PFT | | | | | ļ | | | | | | |
| EXT | OF | | | <u>}</u> | | | <u> </u> | | · | | · |
| | | | | | | | | | | | |
| BT | OF | | | | | | | | | | |
| Te- | OF | | 1251 | | 1256 | | 1251 | | 1056 | | |
| | | | | , | | | 4624 | | 1270 | | |
| Ts2 | Of | | 1233 | ļ | 1235 | | 1236 | [| 1233 | | |
| Teo | Οŗ | { | 1255 | | 1252 | ļ | 1250 | | 101.9 | | |
| 101 | _ <u>r</u> | | 4620 | <u> </u> | <u> 4651</u> | f | H626 | <u> </u> | 1210 | | <u></u> |
| C* | ft/sec | | 2953 | | 2950 | | 2952 | [| 2968 | | 29/17 |
| 127 | 71 | | 278 1 | | 270 0 | | 280 1 | | 070 F | <u> </u> | 290.0 |
| <u> </u> | <u>L0</u> | ł | ELVer | <u> </u> | 121200 | <u> </u> | 10014 | <u> </u> | 617.3 | | |
| Ізр | 500 | | 122.0 | | 121.8 | ļ | 121.9 | | 122.6 | | 121.7 |
| Warm | Th/sec | | 0.00 | <u> </u> | 0.20 | | 0.00 | | 0.00 | | |
| "COLL | 10/ 800 | <u> </u> | <u> <u> </u></u> | <u> </u> | <u> 2 + 30</u> | | 2.30 | <u> </u> | 20 | | 2.30 |
| Fcorr | τO | | 279.5 | _ | 280.0 | | 280.4 | | 280.0 | | 280.4 |
| Do Abr | Conn | | 208 5 | · | 200.0 | | 000.5 | | 000.0 | <u> </u> | 200.5 |
| FU AUS | vorr | <u> </u> | 27000 | + | | <u> </u> | -//•/ | <u> </u> | | | -//•/ |
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Sec. Sec.

| At. = .' | 7040 jn ² | | Tos | t No. I | _{.D-} 34 | to In | _ 38 | | | | |
|-----------------|---------------------------------------|--|-----------------|------------|-------------------|-------------|---------------|--------------|---------|------------|--------------|
| TEST N | | I'l | - 34 | I,D- | 35 | I,D- | 36 | LD- | | <u>[]]</u> | - 38 |
| SURATI | CM 800 | 29 | •4 | 29, | 2 | 22, | 8 | 30. | | 30 |) , 0 |
| TIME | F DATA | Static | 28.9 | <u> </u> | 22.1 | Statio | 29.3 | Static | 29.6 | Static | 29.5 |
| | | | | | | | | 0.012 0.12 0 | | 1744.01 0 | |
| LNP | psig | | 282 | | 283 | | 284 | | 283 | | 284 |
| DND | | | 080 | | 082 | | 008 | | 0.01 | | |
| 4111 | hore | | 202 | | 205 | | 202 | | 204 | | 204 |
| GOP | paig | | 290 | | 286 | | 292 | | 291 | | 293 |
| FT.D | | | Lor | | 1.00 | | 130 | | 1.00 | | 1.00 |
| <u>с для</u> | hork | | 407 | <u> </u> | 400 | | | í | 409 | | 409 |
| LP | psig | 531 | 429 | 534 | 430 | 535 | 432 | 535 | 131 | | 432 |
| | | 500 | 1.00 | | | | 1.0- | 222 | 1.00 | | |
| TP | para | 532 | 483 | 539 | 490 | 537 | 487 | 530 | 488 | | 488 |
| ΔP | psi | | 34.7 | | 35.2 | | 35.6 | | 34.7 | | 35.5 |
| | | | | | | | | | | | |
| W | 10/800 | | 2.28 | | 2.29 | | 2,30 | | 2,28 | | 2.30 |
| DNT | OF | | 1314 | | 1350 | | 1358 | | 13/17 | | 1356 |
| | | · · · · | | | | | | | | | |
| RNT | - OF | | 1349 | | 1342 | | 1354 | | 1338 | | 1347 |
| OOT | | | 1358 | | 1361 | | 1365 | | 1251 | | 7318 |
| | · · · · · · · · · · · · · · · · · · · | | | , | -204 | · · · · · · | | · · · · · · | | | |
| FLT | ok | ······································ | | | | | | | | | |
| DEM | | | | | | | | | <u></u> | | |
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| EXT | ЧO | | | | | | | | | | |
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| | | | | + | | | | | | | |
| Ts ₁ | -TC | | 1251 | | 1256 | | 1254 | | 1256 | | |
| 7 | OF | ļ | 1022 | ļ• | 1025 | | 1026 | | 1022 | | |
| 102 | | | 1222 | <u> </u> | 1222 | | 1230 | | 222 | | |
| T53 | o _F | | 1256 | | 1257 | | 1252 | | 1248 | | |
| | <u>At /</u> | | 2052 | | 2050 | | 0050 | l | 0069 | | 0017 |
| | 17/300 | | 6722 | | 6920 | | 6726 | | 2900 | | 2947 |
| F | 16 | | 278.1 | | 279.0 | | 280.4 | | 279.5 | | 280.0 |
| Terr | | ļ | 100 0 | | 101 0 | | 101 0 | | | | |
| 1 <u>5</u> p | 99 ¢ | ┢──── | HKG øQ. | <u> </u> | HKLO. | | <u>121.89</u> | <u> </u> | 122.Q_ | | 121.7 |
| Wcorr | lb/sec | L | 2.29 | 1 | 2.30 | | 2.30 | [| 2.28 | | 2.30 |
| H. | 15 | ┣ | 070 8 | | 280.0 | | 080 L | <u> </u> | 280.0 | | 280 1 |
| L'COLL | | | <u>6.17.92.</u> | • | | | E00+4 | <u> </u> | | <u> </u> | EVVIA |
| Po Aba | Corr | | 298.5 | | 299.0 | ļ | 299.5 | ļ | 299.0 | | 299.5 |
| | | | | | | | | { | | | |
| | | · · · · · · · · · · · · · · · · · · · | <u> </u> | <u>†</u> | 1 | | | | | | |

Shoot 1 of 2

| Test Item SN | 1 Test No. LD- 39 thru LD- 43 | Test Item | SRLD |
|---------------|-------------------------------|---------------|------------|
| Date | October 21, 1960 | Work Order | 2228-025 |
| Test Engineer | F. A. Urbaniak, 1st shift | Test Facility | <u>W-1</u> |

TEST:

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Gas generator

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS :

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No noticeable drop in nozzle pressure was recorded in these runs.

Left nozzle temperature did not record during runs LD-h0 and 41. (30-second duration firings).

DATA RECORDED ON: Speedomax

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302.00

| At = | .7040 1 n ² | | 'Pos | t No. 1 | I.D- 39 | to H | 1- 113 | | | | |
|-----------------|------------------------|----------|----------|----------|----------|-------------|------------|----------|----------|--|--------------|
| TEST | VC. | Ţ.] | 5. 39 | 1,1)- | - 40 | LD- | 11 | L.D- | 112 | <u>(()</u> | - 13 |
| DURAT COURA | ICN see | 2 | 9.8 | 30. | <u>}</u> | 30 | 0 | 29 | . 2 | 22 | .8 |
| 2:008A1 | CICN SOC | 1.1 | 33.9 | 1161 | •3 | 1194 | • <u>3</u> | 1224 | 2 | 1251 | 1.0 |
| 1 J. 199 (| <u> </u> | nuaure | <u> </u> | ouaun.c | 29.9 | Static | 29.5 | Static | 29.11 | Static | 29.3 |
| LNP | Dale | <u> </u> | 285 | | 285 | | 288 | <u> </u> | 285 | | 286 |
| | | | | | | <u></u> + | | | 202 | | 200 |
| RNP | psig | <u> </u> | 281 | | 284 | | 288 | | 285 | | 285 |
| | | | •` | | | | | 1 | | | |
| (iOP | psig | | 292 | | 291 | | 295 | | 292 | | 291 |
| - WT D | | ļ | | | | ļ | | | | | |
| <u> </u> | parg | <u> </u> | | | 109 | | 1415 | | 7127 | | <u>_h10_</u> |
| LP | naie | 533- | 1:30 | 633 | 1.32 | 537 | 1.36 | 521. | 1.30 | 522 | 1.20 |
| | | | 4211 | -222 | | | 420 | 224 | 424 | | <u> </u> |
| TP | psig | 540 | 490 | 539 | 490 | 542 | 494 | 539 | 1190 | 538 | <u>188</u> |
| | | | | | | | | | | | , |
| <u>_</u> P | psi | | 35.5 | | 35.5 | | 36.3 | | 35.5 | | 35.4 |
| - W | Thicks | | 0.00 | | 0.20 | · · · | | | | | |
| <u> </u> | 10/ 860 | | 2.30 | | 2.30 | | 2.33 | | 2,30 | | 2.29 |
| LNT | · OF | | 1352 | | | | | | | | |
| | · | | | | | | · · | | | | |
| RNT | OF | | 1350 | | 1360 | | 1352 | | 1374 | | 1355 |
| | | | | | | | | | | | |
| GOT | ¥ | | 1359 | | 1347 | | 1344 | | 1382 | | 1360 |
| 100 m | Cher | | · | | | | ļ | | | | |
| <u></u> | F | | | | | ¦ | | | | · | |
| PFT | - Pro- | | | | | | <u> </u> | · | | | |
| | | | | | | | h | | | | |
| EXT | OF | | | | | | | | | | |
| Dr. | Otr | | | | | L | | | | | |
| <u> </u> | F | | | | | | <u> </u> | | | | · |
| T81 | . OF | | 125/1 | | 1206 | | 1217 | | 1218 | | 1268 |
| | | 1 | | | | | | | | | |
| Ts ₂ | ok | | 1256 | | 1221 | | 1221 | | 1167 | | 1206 |
| | | | | | | | | | | | |
| <u></u> | ch. | | 1252 | | 1241 | | 1238 | | 1261 | | 1247 |
| C* | ft/sec | | 2952 | | 2952 | | 201.8 | | 2057 | | 2075 |
| | | | | | | | | | <u> </u> | | |
| F | 16 | | 280.4 | | 280.4 | | 283.7 | | 280.9 | | 281.4 |
| | | | 101 0 | | 101 0 | | 3 03 0 | | | | |
| Isp | 596 | | .L21.y | | 121.9 | | 151.9 | | 155.1 | | 122.9 |
| Wearr | 10/ 500 | | 2.30 | | 2,30 | ┝ <i>──</i> | 2.31 | | 2,30 | | 2.20 |
| | 4 | | | | | | | | | | |
| Foorr | Ib | | 280.0 | | 280.9 | | 281.1 | | 280.4 | ······································ | 281.4 |
| | 0 | | 200 0 | <u> </u> | 200 0 | | 200 | | | | |
| LLG VOR | UOFF | | ~yy.U | | 200.0 | | 1900.2 | | 299.5 | · ····· | 300.5 |
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Sheet 1 of 2

| Teat Item SN | 1 Test No. LD- 44 thru LD- 4 | 7 Test Item | SRLD |
|---------------|------------------------------|---------------|------------|
| Date | October 21, 1960, 2nd shift | Work Order | 2228-025 |
| Test Engineer | H. M. Graham | Test Facility | <u>W-1</u> |

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Gas Generator

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS:

No noticeable drop in nozzle pressure was recorded in these runs (30-second duration firings).

DATA RECORDED ON: Speedomax

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CONTRACT.

Test No. LD- 44 to LD- 47

| TEST NC. | | LD-44 | | I.D- 45 | | I.D- 46 | | LD-, 1.7 | | I.D- | |
|-------------|------------------|--|--------|----------|----------|-----------|---------------------------------------|-----------|--------------|----------|-------------------------------|
| | W Sec | 30 | .0 | 29. | .7 | 22. | 7 | 30.5 | | | |
| TIME OF | T DATA | Static | 29.5 | Static | 20.2 | statio | 4 | Statta | 30.0 | Static | |
| | | | -7-7 | | 2/02 | DUAULO | | DUGULI | | | |
| LNP | psig | | 284 | | 286 | | 286 | | 287 | | |
| UND | | | 695 | | AVE | | 0.97 | | 0.92 | | |
| RNP | parg | | 205 | | 205 | | 200 | | 200 | | |
| GGP | psig | · · · · · · · · · | 291 | | 293 | | 292 | | 294 | | |
| | | | | | | | | | 1 | | |
| ۳ <u>با</u> | para | <u> </u> | 410 | | 414 | | 412 | | <u>////2</u> | | |
| LP | psig | 532 | 433 | 535 | 434 | 533 | 433 | 538 | 137 | | |
| | | | | | | | | | | | |
| TP | psig | 538 | 489 | 542 | 491 | 538 | 489 | 543 | 494 | | |
| ΔP | psi | | 35-4 | | 35-6 | | 35.5 | | 36-0 | | ,^ ~~ ~~ ~~ ~ ~~~~ |
| | | | | | | | | | | | ··· |
| W | 10 580 | | 2.29 | | 2.30 | | 2.30 | | 2.32 | | |
| LINT | · OP | <u> </u> | | | | | | | | | · |
| | <u>_</u> | <u> </u> | | | | | ļ' | | | | <u>i</u> |
| RNT | OF. | | 1362 | | 1369 | | 1364 | | 1358 | | |
| 007 | | | 1330 | | 1350 | · · · · · | 1361 | | 1267 | · | ! |
| UUT | <u> </u> | <u> </u> | 02,22 | | 050 | | 1204 | | +201 | <u> </u> | |
| FLT | - F | | | | | | · · · · · · · · · · · · · · · · · · · | | | | |
| | | · · · | | | | | | | | | |
| PFT | - | | | | | | | | | | |
| EXT | OF | | | | | | | | | | |
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| BL. | <u> </u> | <u> </u> | | | <u> </u> | | <u> </u> | · | | | |
| Ts1 | o F. | | 1268 | | 1267 | | 1271 | | 1256 | | |
| | | | | · | | | | | | | |
| T 52 | ~F | ┥───- | 1217 | ł | 1215 | | 1216 | | 1559 | | |
| T83 | o _F . | t | 1240 | | 1242 | | 1211 | | 1216 | | |
| | | | 0.055 | | 00/0 | | 0.0/- | | | | |
| <u>C*</u> | ft/sec | ł | 2925 | | 2962 | | 2967 | | 296 | | * |
| F | 15 | <u>† </u> | 279.5 | | 281.4 | | 281.0 | | 282-3 | | |
| | | | | [| | | | | | | |
| Isp | 890 | <u> </u> | 122.1 | | 1755 - 3 | | 122.5 | <u> `</u> | 121.7 | | |
| Wcorr | 1b/ soc | 1 | 2.29 | | 2.30 | | 2,29 | | 2.31 | | |
| | | | | | | | | | | | |
| P'corr | 10 | | 279.5 | | 281.4 | | 280.9 | <u> </u> | 282.4 | | • |
| Pc Abs | Corr | | 298.5 | <u> </u> | 300.0 | | 300.0 | | 300-5 | | |
| | | | | | | | | | | | |
| | . <u> </u> | <u> </u> | ┢┈──── | | { | | <u> </u> | | ł | <u> </u> | <u> </u> |

| | | Sheet 1 | of |
|---------------|-----------------------------|---------------|------------|
| Test Item SN | 1 Test No. LD- 48 thru LD- | Test Item | SRLD . |
| Date | October 27, 1960, 1st Shift | Work Order | 2228-025 |
| Test Engineer | L. Goldschlag | Test Facility | <u>W-1</u> |

TEST:

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Gas Generator Assembly.

PURPOSE:

Reliability testing of the gas generator assembly and detormination of torque required to move the swivel nozzle assembly.

REMARKS:

Prior t) this test the swivel nozzles and manual remote actuating rod were installed on the test assembly. Thermocouples for measuring the propellant feed temperature and for measuring the temperature of the lift ring mount bracket were also installed.

No noticeable drop in nozzle pressure was recorded in this run. Left nozzle temperature did not record.

Tank pressure was increased in several steps.

DATA RECORDED ON: Speedomax

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| TEST NO | · · · · · · · · · · · · · · · · · · · | T.I | 5_ 48 | LD_ | 48 | 1.1) | | LD- | 1.53.54 - 54. 1.55 | LD. | |
| DURATIC | N BOC | 147 | •0 | | | | | | | | |
| ביזטוריצ | CN see | · | ويسونيا معديني والمراد | 142 | 0.9 | | | | | | |
| TIME OF | ' DATA | Stathe | 10.0 | 20.0 | 40.5 | Static | | Static | | Statio | |
| TND | | | 302 | | | | | | | | |
| | psig | | 170 | 240 | 320 | | | | | | |
| RNP | nede | | 7121 | 21.0 | 201 | | | | | | |
| | par6_ | · | 1211 | 240 | 24.4 | | | | | | |
| COP | psig | | 183 | 257 | 331 | | | | | | |
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| FLP | psig | | 250 | 354 | 466 | | | · · · · · · · · · · · · · · · · · · · | | | |
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| LP | psig_ | 298 | 259 | 370 | 492 | Í | | | | | |
| | | | 0.00 | | 172 | | | ······ | | | |
| 1 TP | psig | 204 | 207 | | 200 | | | <u> </u> | | | |
| AP | | | 122 | 28 7 | 16 7 | | | | | | ļ |
| | po.c | | 12+0 | 20.01 | 40.1 | | | | | | |
| W | 1b/sec | <u> </u> | 1.56 | 2.09 | 2.62 | | | | | | |
| | | | | ~ 07 | L | ····· | | | · · · · · · · · · · · · · · · · · · · | | |
| LNT | · OF | | Lost | 1131 | 1153 | | | - | | | |
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| RNT | OF | Open | Thermon | ounle | | | | | | and a second sec | |
| | | | | | | | | | | | |
| GOT | | | 1406 | 1408 | 1414 | | | | | | |
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| FLT | | | | | <u> </u> | | | | | | |
| - DE | | 63 | 12 | 52 | | | | | · · · · · · · · · · · · · · · · · · · | | · |
| | . | | <u> </u> | - 20 | 27 | | | | | | |
| EXT | OF | | | | | | | | | | |
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| BT | OF | 64 | 68 | 77 | 90 | | | | | | |
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| Ts1 | | | | | <u> </u> | | | | | | |
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| C* | ft/sec | | 2783 | 2853 | 2903 | i | | | | | |
| | | | | | | | | | | | |
| F | 16 | | 179.3 | 246.2 | 314.1 | | | | | | |
| | | <u> </u> | | | | | | | | ļ | |
| Isp | sec | ļ | 114.9 | 117.8 | 119.9 | | | | | | |
| 1.1 | | ÷ | 3 31- | | 0.10 | | | | | | |
| - corr | 10/ 800 | | E 6 G . J . | <u> </u> | 6940 | | | | | <u> </u> | |
| Foorr | 16 | + | 251.2 | 272.5 | 287.9 | | | | | | |
| | | | 1 | | | | | | | | |
| Pc Abs | Corr | 1 | 271.5 | 291.0 | 307.5 | [| | | | | |
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Sheet 1 of 2

| Test Item SN | 1 Test No. LD- 49 thru LD- | Test Item | SRLD |
|---------------|----------------------------|-------------|------------|
| Date | October 27, 1960 | Work Order | 2228-025 |
| Test Engineer | L. P. Sileo, 2nd Shift Te | st Facility | <u>W-1</u> |

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Gas Generator

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS:

No noticeable drop in nozzle pressure was recorded in this run (30-second duration firing).

DATA RECORDED ON: Speedomax

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| TEST NO | TANKAT POWERTY | [.] | 0-119 | <u>[]</u>] | · · · · · · · · · · · · · · · · · · · | I.D- | | <u>[]]</u> - | ************** | T.D. | |
| DURATIC | N 800 | 2 | 9.9 | | | | | | | | |
| <u>STURAT</u> | ICN 800 | 145 | 0.8 | ,. | | | | | | | |
| TIME (1 | <u> </u> | Stat.c | 29.4 | Statid | | Statio | | Static | | Static | |
| 7 500 | | | | L | | | · | | | · | |
| 1.01. | psig | | 285 | | | | | | | | |
| DND | | | 007 | | | | <u>.</u> | | | | |
| 1/141 | barg | | 205 | | | | | | | | |
| GOP | Dalg | | 203 | | | | | | ······································ | | |
| | | | 672 | | | | | | | | |
| FLP | psig | | 110 | | | | | | | | |
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| LP | psig | 531 | 429 | | | | | | | | |
| | | | | | | | | | | | |
| TP | psig | 540 | 488 | | | | | | | | |
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| _ <u>_</u> P | psi | | 35.8 | | ļ | | | | | · | |
| | | | | | <u> </u> | | | | <u> </u> | <u>,</u> | |
| W | TON SOC | | 12.31 | | <u> </u> | | | | h | | <u>├</u> |
| TND | | | | | | | | | | | |
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| GOT | O _F | <u> </u> | 1301 | | | | | | | | |
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| FLT | | | <u> </u> | <u> </u> | | | | | | | |
| | <u> </u> | | <u> </u> | · | | | | | | * | |
| PFT | | 54 | 53 | | † | | | | | | |
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| T83 | o _F | <u> </u> | 1 | | 1 | [| | | [| | |
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| <u>C</u> * | ft/sec | | 2944 | | | | | | | | |
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| F | 16 | <u> </u> | 280.9 | | | | | | | | |
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| 150 | <u></u> | <u> </u> | TSTO | <u> </u> | <u> </u> | | | } | | | <u> </u> |
| Warne | 1b/sec | <u> </u> | 2.11 | <u> </u> | <u> </u> | | | | | | |
| - COLL | 1.0/ 800 | <u> </u> | 1 . • | <u>}</u> | <u> </u> | | | h | | | ┟╌┈──┤ |
| Fcorr | 16 | <u> </u> | 280-9 | | † | | | <u> </u> | | ; | <u> </u> |
| <u></u> | | t | | <u>† , </u> | t | | ┝──┉╼╼╼╼╼╼ | | h | <u> </u> | t |
| Pc Abs | Corr | | 300.0 | | [| [| | | | | |
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Sheet 1 of 1

| Test Item SN | 1 Test No. LD- 50 thru LD- 5 | <u>3</u> Test Item | SRLD |
|---------------|------------------------------|--------------------|----------|
| Date | October 28, 1960 | Work Order | 2228-025 |
| Test Engineer | L.Goldschlag, 1st Shift | Test Facility | W-1 |

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Gas Generator Assembly

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS :

No noticeable drop in nozzle pressure was recorded in these runs (30-second firings).

DATA RECORDED ON: Speedomax

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| At = . | 7040 1nº | | ២០១ | t No. I | D- 50 | to ID | - 53 | | | | |
|-----------------|--|----------|----------|---------|--------------------|--|---------------------|---------------------------------------|---------|--------------------|-----------|
| TEST N | C. | [,T | 5- 50 | [,])_ | 51 | LD- | 52 | [.]])-, | 53 | Ť,D. | |
| בדעצוות_ | CN SOC | 30. | 1 | 29. | 9 | 30. | b | 30 | 0 | | |
| S TOURAT | TON SOC | 1481 | .2 | 1511 | .1 | 154 | 1.1 | 15 | 71.1 | | |
| TIMEC | אייאכן יוי | Static | 29.9 | Statig | 29.li | Static | 29.5 | Static | 29.5 | Static | |
| | | | | | | | | | | | |
| LNP | psig | | 286 | | 282 | | 285 | | 283 | | |
| | ······································ | | | | | | | | | | |
| RNP | psig | | 287 | | 283 | | 285 | | 284 | | |
| | | | | | | | | | | | |
| NOP | psig | | 294 | | 291 | | 292 | | 292 | | |
| | | | | | | | | | | | |
| FLP | psig | | 415 | | 408 | | 411 | | 412 | | |
| | | | | | | | | | | | |
| LP | psig | 537 | 435 | 529 | 431 | 531 | 432 | 530 | 430 | | |
| | | | | | | | | | | | |
| TP | psig | 543 | 492 | 536 | 488 | 540 | 492 | 490 | 537 | | |
| | | | | | | | | | | | • |
| ΔP | p si | | 35.7 | | 35.1 | | 35.6 | | 35.6 | | |
| | | | | | | | | | | | |
| W | lb/sec | | 2.30 | | 2.28 | | 2,30 | | 2.30 | | |
| | | | | | | | | | | | |
| LNT | - Act | · | 1336 | | 1330 | | 1362 | | 1338_ | | |
| | | | | | | | | | | | |
| RMU | Ur | No Re | pord | | 1330 | | 1276 | | 1340 | | |
| | | | 9829 | | 1 1 1 | | 3010 | | 1070 | | |
| | - H. | | 1301 | | 13/4 | · | 1343 | | 1001 | | |
| - TAT /A | | | | | | | | | | | |
| L [1] | -1 | · | | | | | | | | | |
| DIV | | 51 | 1.6 | 67 | 1.8 | 70 | 1.8 | - 22 | 27 | | |
| 1.4.4 | <u>4'</u> | <u> </u> | 40 | | 40 | 10 | 40 | | 21 | | |
| EXT | OF | | | | | | | | | | |
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| BT | or | 53 | 74 | 63 | 86 | 65 | 88 | 53 | 86 | | |
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| Tsi | o _F | | | | | | | | | | |
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| <u>T83</u> | <u> </u> | | ļ | | | | | | | | |
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| <u>C</u> * | ft/sec | | 29/2 | | 2950 | L | 2721 | | 2942 | | |
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| <u>r</u> | 10 | | 202.3 | | 1 <u>< (0.5</u> | •••••••••••••••••••••••••••••••••••••• | 200.9 | | 6 17 .2 | ••••••• | |
| Ter | | <u> </u> | 122 2 | | 100 1 | | 122 1 | | 101 6: | | |
| -1.9h | 660 | | | | ↓ <u>₩₩₩</u> ₩₩ | | <u>ار ه ک ک خ</u> ر | | | | |
| Woorr | 1.b/sec | <u> </u> | 2.28 | | 2.29 | | 2.30 | | 2.29 | | |
| | <u></u> | † | | | | | | | | | |
| Fcorr | 1.b | | 280.0 | | 279.5 | | 280.4 | | 278.5 | $\mathbf{\Lambda}$ | |
| | | | | | | | | | | | |
| Po Abs | Corr | ļ | 299.0 | | 298.5 | | 299.5 | · · · · · · · · · · · · · · · · · · · | 297.5 | | |
| | | | | | | | | | | | |
| | | | L | | J | | | | | | |

Sheet <u>1</u> of <u>3</u>

| Test Item SN | 1 Test No. LD- 5h thru LD- 61 | Test Item | SRLD |
|---------------|-------------------------------|---------------|------------|
| Date | October 28, 1960 | Work Order | 2228-025 |
| Test Engineer | L. P. Sileo, 2nd Shift | Test Facility | <u>W-1</u> |

TEST:

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Gas Generator Assembly

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS :

No noticeable drop in nozzle pressure was recorded (30-second duration firings).

DATA RECORDED ON: Speedomax

CHILL West

Sheet 2 of 2

| At = . | 7040 in ² | | Tost | No. | .D- 511 | to ID | - 61 | | | | · · · · · · · · · · · · · · · · · · · |
|--------|----------------------|-------------------------|-------------|-------------|-----------|--------------|-------|--|-------|----------|---------------------------------------|
| TEST N | | анын н санаса [] | <u>- 91</u> | <u>-(,)</u> | 55 | <u>-([,]</u> | 56 | <u>ID-</u> | 57 | 1))- | . 58 |
| | CN SOC | 29. | 5 | <u></u> | <u>•2</u> | 30. | .0 | 1691 | | 1721 | 1 |
| TIME | F DATA | Statie | 29.0 | Junti o | 29.1 | Static | 30.3 | Static | 29.6 | Static | 29.2 |
| LNP | psig | | 286 | | 285 | | 283 | ander (1 p. 47 - 14 - max b 47 a 19 - | 284 | | 284 |
| RNP | psig | | 287 | | 286 | | 284 | | 284 | | 286 |
| GOP | psig | | 293 | | 295 | | 291 | | 292 | | 292 |
| FLP | psig | | 1111 | | 413 | | 409 | | 411 | | 115 |
| LP | psig | 538 | 437 | 541 | 138 | 532 | 1,33 | 525 | 435 | 538 | 434 |
| TP | psig | 541 | 494 | 543 | 495 | 536 | 489 | 539 | 795 | 541 | 489 |
| A٩ | psi | | 36.1 | | 36.3 | | 35.1 | | 36.0 | | 36.1 |
| W | lb/sec | | 2.32 | | 2.33 | | 2.28 | | 2.32 | | 2.32 |
| LNT | , or | | 1348 | | 1353 | | 1354 | | 1352 | | 1355 |
| RNT | Oŀ. | | 1354 | ` | 1350 | | 1332 | | 1338 | | 1344 |
| COT | 0 _F | | 1379 | | 1369 | | 1367 | | 1372 | | 1356 |
| FLT | о ў . | | · | | | | | | | | |
| PFT | | 59 | 56 | 67 | 55 | 72 | 54 | 66 | 53 | <u> </u> | 52 |
| EXT | | | | | | | | | | <u> </u> | |
| BT | | <u> </u> | | | | | | | | | |
| T81 | | | | | | | | + | | | |
| 182 | | | | | | | | + | | | |
| 183 | | | 2016 | | 2921 | | 2968 | | 2922 | | 2936 |
| | 16/ 580 | + | 282 2 | <u> </u> | 287 1 | • | 279.5 | | 280-0 | | 293.6 |
| Ten | | + | 121.7 | + | 120.7 | | 122.6 | | 120.7 | | 121.3 |
| Wach | 1b/sec | | 2.30 | <u>+</u> | 2.32 | + | 2.28 | | 2.32 | | 2.31 |
| Fcorr | 15 | | 260.4 | | 280.0 | | 280.0 | | 279.5 | | 280.0 |
| Pc Abs | 3 Corr | | 299.5 | | 299.0 | | 299.0 | | 298.5 | | 299.0 |
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Sheet <u>3</u> of <u>3</u>

| AT = | -7040 hh~ | _ | TOS | t No. I | .D- 54 | _ to II | <u> </u> | | | | |
|---------------|------------|----------------|--------------|--------------|----------|----------|------------------------------|---------------------|--------------------------|------------|------------------------|
| TEST | NC. | . LJ | 5- 59 | I.D- | 60 | LD- | 61 | LD- | | LD. | |
| DURAT | ICN SOC | 30- | 0 | 29. | 8 | 11. | | | | [| *********** |
| STURA' | TTCN SOC | 1761 | | 1720 | 0 | 1822 | مرت روستان (2 | | | | |
| TIME | OF DATA | Static | 20.5 | Static | 20.3 | Statio | 30.0 | Chatta | 1.0.0 | Ch 0 4 3 0 | ····· |
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| RNP | psig | | 284 | | 264 | | 205 | | 205 | | |
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| GOP | psig | | 293 | | 291 | | 291 | | 292 | | |
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| FLP | paig | | _ ம | <u> </u> | 410 | | 413 | | 413 | | |
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| LP. | pate | 538 | 435 | 536 | 433 | 535 | 136 | | 136 | | |
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| TP | psig | 540 | 1190 | 538, | 490 | 538 | 492 | | 492 | | |
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| ΔP | · psi | | 36.2 | | 35.7 | | 36.2 | l | 36.2 | | |
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| W | 1b/sec | l | 2.33 | | 2.30 | | 2.33 | | 2.33 | | |
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| RNT | OF. | | 1318 | <u>}</u> | 13/0 | | 13/0 | | 13)/7 | | |
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| COT | Our | | 1362 | | 1271 | | 1260 | | 1262 | | |
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| | A | <u> </u> | 2071 | <u>├</u> ─── | 0010 | | 2011 | | 2011 | | |
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| 1-1 | | | 280.0 | <u> </u> | 270 8 | | 070 0 | | 000 0 | | |
| <u>corr</u> | <u> </u> | + | | ł | 612.2 | | GIY.U | _ | E12.0 | | <u></u> |
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Sheet 1 of 2

| Test Item SN | 1 Test No. LD- 62 thru LD- 6 | 5 Test Item | SRLD |
|---------------|------------------------------|---------------|------------|
| Date | October 31, 1960 | Work Order | 2228-025 |
| fest Engineer | L. Coldschlag, 1st Shift | Test Facility | <u>W-1</u> |

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53

Gas Generator Assembly.

PURPOSE:

Reliability testing of the gas generator assembly.

REMARKS :

No noticeable drop in nozzle pressure was recorded (30-second duration firings).

DATA RECORDED ON: Speedomax

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Sheet 2 of 2

| At $=$. | 7040 in" | | Tos | t No. I | ,D- 62 | to II | - 65 | | | | |
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| TEST N | C. | T,J |)- 62 | I,D- | 63 | I.D- | 64 | LD- | 65 | -۲ ^۰ ۵ | |
| DURATT | CM 800 | 29. | 6 | 29 | 8 | 30 | 5 | 30 | 4 | | |
| <u>ENURAT</u> | ICN BOC | 185 | 1.9 | <u>1881</u> | •7 | 191 | 2.2 | 19/ | 2.6 | | |
| TIMEO | F DATA | Static | 29.1 | Static | 29.3 | Static | 30.1 | Statio | 29.9 | Static | |
| | | | | | | | | | | | |
| LNP | psig | | 284 | | 284 | | 286 | <u> </u> | 287 | ┢╾╼╾┥ | |
| DNB | | | | | | | | | | + | |
| ICMP | parg | | 284 | | 202 | | 287 | ┢ | 286 | ┟╍╍╍┟ | |
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| | Pore | | 271 | | 209 | | 290 | <u> </u> | 292 | ╉╼╼╼╼╋ | |
| FLP | Daig | | 112 | | 110 | | 1.73 | + | 1.73 | ++ | |
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| LP | psig | 538 | 437 | 533 | 135 | 543 | 1112 | 540 | בווע | | |
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| TP | psig | 538 | 493 | 532 | 486 | 539 | 492 | 540 | 493 | | |
| | | | | | | | | | | | |
| ΔP | pai | | 35.6 | | 35.3 | | 36.5 | | 36.4 | | |
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| COT | OF | | 1377 | | 1356 | | 1356 | + | 1376 | 1 | |
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| FLT | ok | | | | | | | | | | |
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| PFT | <u> </u> | 58 | 49 | 69 | 52 | 71 | 53 | 64 | 54 | | |
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| T82 | <u>ok</u> | [| | | | | | I | | Ι | |
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| <u>T83</u> | ok | <u> </u> | L | | | L | | | | ╉╍╍╍╍╍┥ | |
| | Ph / and | | 2019 | <u> </u> | 2050 | | 2027 | <u> </u> | 0022 | ╋━━━━╋ | |
| <u> </u> | 10/360 | - | 4241 | <u> </u> | 6720 | | 14X6- | t | נגעא | ╉┉┈┈╋ | |
| W | <u></u> | <u> </u> | 280-0 | <u> </u> | 279-0 | | 282.3 | <u>+</u> | 282.3 | | |
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| Isp | 80C | | 121.7 | | 121.8 | | 1.20.6 | | 121.2 | | |
| | | | | | | | | | | | |
| Wcorr | 1b/sec | | 2.29 | | 2.29 | | 2.33 | ļ | 2.32 | <u></u> | |
| | | | 070 0 | | 0.00 | <u> </u> | 000 0 | | | ╉╾╍╍╍╍┝ | |
| <u> ° corr</u> | <u> </u> | <u> </u> | KIYO | | KIX.0 | <u> </u> | K00.9 | <u> </u> | K00-9_ | ╬╾╍╍╍╆ | |
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| Sheet | | 1 | of | 3 |
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| Test Item SN | 1 Test No. LD-66 | thru LD-: 72 | 2 Test: Item. | SRLD |
|---------------|---------------------|--------------|---------------|------------|
| Date | October 31, 1960 | • • | Work Order | 2228-025 |
| Test Engineer | L. Sileo. 2nd Shift | | Test Facility | <u>W-1</u> |

TEST:

Gas Generator Assembly.

PURPOSE:

.

Reliability testing of the gas generator assembly.

REMARKS :

No noticeable drop in nozzle pressure was recorded (30-second duration firings).

DATA RECORDED ON: Speedomax

sheet 2 of 3

| At = . | $7040 \mathrm{m}^2$ | | Tes | t No. I | .D- 66 | _ to LL | - 72 | | | | |
|-----------------|---------------------------------------|--------------|----------|---------------------------------------|----------|----------|------------|----------------|----------|----------------------|----------------|
| TEST N | <u>ا</u> ۲. | LI | 5- 66 | T,D- | 67 | L.D- | 68 | LD- | 69 | מזי | - 70 |
| TURATI | CN SOC | 29 | •6 | 31. | 7 | 31, | 6 | 31, | 2 | 30,8 | |
| SUURAT | TON SOC | 197 | 2.2 | 200 | 3.9 | 2035 | •5 | 2066 | •7 | 209 | .5 |
| TIMEC | F DATA | Static | 29.1 | Static | 31.2 | Static | 31.5 | Static | 30.7 | Static | 30.3 |
| TAID | | | 0.07 | | 0.05 | | 007 | | 0.97 | | |
| LINP | psig | | 201 | | 205 | | 207 | | 200 | | 200 |
| DND | neia | ┟ | 287 | | 082 | | 0.02 | | 0.07 | | 000 |
| | | | 201 | | 205 | | 200 | | 201 | | 202 |
| GOP | psig | | 202 | | 280 | | 202 | | 202 | | 202 |
| | | | /- | | | | <u> </u> | | <u> </u> | | 676 |
| FLP | psig | | 116- | | 110 | | Lil | | 113 | | 113 |
| | | | | | | | | | | | |
| LP | psig | 540 | 440 | 530 | 430 | 534 | 435 | 536 | 136 | 535 | 137 |
| | | | | | | | | | | | |
| TP | psig | 544 | 495 | 537 | 490 | 538 | 490 | 538 | 491 | 51.0 | 491 |
| | · · · · · · · · · · · · · · · · · · · | | | | | | | | | | |
| <u> </u> | psi | | 35.7 | | 35.4 | | 36.0 | | 36.0 | | 35.8 |
| 1.5 | | | | | | | | | | | |
| <u> </u> | TDI BAC | | 2.30 | | 2.29 | | 2.32 | | 2.32 | | 2.31 |
| TNT | - OF | | 1216 | | 7214 | <u> </u> | 121.2 | l | 121.7 | | 1250 |
| | | ╂ | 10110 | | <u></u> | <u> </u> | 1242 | | 1241 | | . 1020 |
| RNT | | <u> </u> | 1331 | | 1332 | | 1221 | | 1320 | | 1326 |
| | | | | | | | | | | | |
| OGT | F | Unreli | able | | 1382 | <u> </u> | 1379 | | 1382 | | 1371 |
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| FLT | ন্ত | <u> </u> | | · · · · · · · · · · · · · · · · · · · | | ł, | 7 | | | | |
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| PFT | | .59 | 55 | 69 | 55 | 72 | 54 | Unrel: | able | 68 | 53 |
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| EXT | 01. | <u> </u> | | | | | ļ. <u></u> | | | | |
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| L | | ļ | 0.000 | | 0070 | | 2017 | <u> </u> | 0012 | | 0015 |
| C* | ft/sec | | 2977 | | 12700 | | 12340 | | 12270 | | 2949 |
| | | + | 282.7 | <u> </u> | 280.0 | <u> </u> | 080.1 | ┟┅──┈── | 282 2 | | 281 1. |
| | T0 | | 20201 | | 1-00.0 | <u> </u> | LUC. 8.J | | 20202 | | CUL⊕4 |
| Tap | 880 | | 122.9 | | 122.3 | <u> </u> | 121.7 | <u> </u> | 121.7 | <u>†</u> i | 121-0 |
| | | <u>+</u> - | <u> </u> | <u> </u> | | <u> </u> | | † | | | |
| Wcorr | lb/sec | | 2.28 | | 2.29 | | 2.30 | | 2.31 | | 2,30 |
| | | | | | | | | | | | |
| Fcorr | 16 | | 280.0 | | 280.0 | | 280.4 | ļ | 280.9 | l | 280_0 |
| L | | <u> </u> | 200 0 | ↓ | 200 0 | | 200 - | | 200 0 | | 200 0 |
| PC ADS | Corr | + | 277.0 | | 277.0 | ╂──── | <u> </u> | ├ ───── | pw.v. | <u> </u> | <u> 877 °O</u> |
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Sheet 3 of 3

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| ETARURIS - | CN SOC | 212 | 8.1 | 2158 | •4 | | | | | | |
| TIME OF | DA'PA | Slatic | 30.1 | Static | 29.8 | Static | | Static | | Static | |
| | | | 0.00 | | 0.00 | | | | | | |
| LNP | psig | | 201 | | 209 | | | · | | | · |
| RNP | psig | | 288 | | 289 | | | | | | |
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| (10) | psig | | 286 | | 294 | | | | | | |
| FLP | psig | | 416 | | 417 | | | | | | |
| | | - 51-0 | 1.1.7 | | | | | | | | |
| LP | psig | 240 | 444LL | 242 | 445 | | | | · · · · · · · · · · · · | | |
| TP | psig | 513 | 495 | 545 | 495 | | | | | | |
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| <u>,</u> Δ _F | psi | | 2•00 | <u>`</u> | 4•0د | | | | | <u> </u> | |
| W | lb/sec | | 2.33 | | 2.33 | | | | | | |
| P.0.776 | | | 1250 | | 121.9 | | | | | | |
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| RNT | OF | | 1331 | | 1330 | | | | | | |
| | 0- | | 1061 | | 3077 | | | | | | |
| GGT | ·F | · · · | 1301 | ļ | 1300 | | | · | | <u> </u> | |
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| PF1 | <u> </u> | 20 | 49 | 00 | 49 | | | | | <u> </u> | |
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| C* | ft/sec | | 2943 | | 2958 | | | | | | |
| | | ļ | 092.0 | | 001. 7 | | | | | | |
| <u>r</u> | 10 | <u> </u> | 203.2 | | 204.0 | | | | | | |
| Isp | sec | | 121.6 | | 122.2 | | | | | | |
| 14 | 16/200 | | 2 31 | <u> </u> | 2.30 | ┠──── | | | | l | ————— |
| " gorr | 10/ 900 | <u> </u> | <u> </u> | <u> </u> | 2020 | | | | | | |
| Fcorr | 16 | | 280.4 | | 281.4 | | | | | ļ | |
| Pc Abe | Corr | | 299.5 | | 300.5 | | | | <u> </u> | | |
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| | | Sheet 1 | of <u>2</u> |
|---------------|----------------------------|---------------|-------------|
| Test Item SN | 1 Test No. LD- 73 thru LD- | 77 Test Item | SRLD |
| Date | November 1, 1960 | Work Order | 2228-025 |
| Test Engineer | L. Goldschlag, 1st Shift | Test Facility | <u>W-1</u> |

TEST:

. . Gas Generator Assembly

PURPOSE :

. .

Reliability testing of the gas generator asrembly.

REMARKS :

No noticeable drop in nozzle pressure was recorded (30-second duration firings).

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DATA RECORDED ON: Speedomax

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| At ≈ .' | $7040 \mathrm{tn}^2$ | | Tos | t No. I | .n- 73 | to LL |)- 77 | | | | |
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| TEST N | | 1,1 | 5- 73 | T,D- | 74 | LD- | 15 | LD- | 76 | T.D. | . 71 |
| DURATT(| TN SOC | 30. | 3 | <u> </u> | ···· ···· | 22. | 7, | 30. | | 30, | 5 |
| TTME C | F DATA | Static | 29.8 | Zelo. | 29.5 | 2240 Statio | 4 | 2270.1 | 20.7 | 2309 | 30.0 |
| | | UNIT O.L.C | 27.0 | 004020 | 676,2 | Dualito | 6.706 | 1004010 | 2201 | SCACLC | |
| LNP | psig | | 288 | | 288 | | 288 | | 288 | | 286 |
| | | | | | | | | | | | |
| RNP | psig | | 288 | | 287 | | 287 | | 288 | | 285 |
| 900 | psig | | 202 | | 292 | | 202 | | 203 | | 200 |
| | | | -/- | | -/- | | <u> </u> | | -// | | |
| FLP | psig. | | 414 | | 117 | | 414 | | 416 | | 412 |
| 715 | | 531 | 1.01. | - E3R | 1.58 | 620 | 1.20 | Eaz | 1.20 | There 7 d | -1-7 |
| PL | psig | 224 | 464 | 020 | 450 | 229 | 409 | 550 | 459 | OULATI | aore |
| TP | psig | 539 | 494 | 539 | 2196 | 549 | 193 | 538 | 192 | 539 | L192 |
| | | | | | | | | | | | |
| _ <u>_</u> _P | psi | | 36.3 | | 36.2 | | 36.5 | | 36.4 | | 35.8 |
| w | 1b/abo | | 2.33 | | 2.33 | | 0.31 | | 2 32 | | 2 21 |
| | 10/000 | | | | 2022 | | 2024 | | <u> </u> | | _ <u></u> |
| LNT | , Ok | | 1330 | | 1340 | | 1343 | | 13/1 | | 13/3 |
| | | | | | | | | | | | |
| RNI | OH- | | 1340 | | 1305 | | 1337 | | 1293 | | 1353 |
| GOT | O _F | · | 1326 | | 1369 | | 1361 | | 1379 | | 1305 |
| | | | | | | | | | | | |
| FLT | oF | 4 18 | | | | | | | | | |
| DEM | | F0 .1 | 50 | ER | 50 | 60 | 22 | | 62 | 50 | 20 |
| <u>rri</u> | | 36 | 22 | 30 | 24 | 00 | 22 | 22 | 22 | -22 | 22 |
| EXT | OF | - | | 53 | 472 | 53 | 462 | 51 | 461 | 52 | 392 |
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| C* | ft/sec | | 2948 | | 2943 | | 2931 | | 2948 | | 2949 |
| | | | 002 7 | | 092 0 | | 000 0 | | 000 7 | | 0.07 |
| | 10 | | 203.1 | | 203.2 | | 202.3 | | 203.7 | | XOL .U |
| Isp | sec | | 121.8 | | 121.6 | | 121.0 | | 121.8 | | 121.8 |
| | | ļ., | | | | | | | | | |
| Wcorr | TD/ Sec | <u> </u> | 2.31 | | 2.31 | | 2.32 | <u> </u> | 2,31 | | 2.30 |
| Foorr | 16 | <u> </u> | 281.8 | | 281.4 | | 281.1 | | 280.9. | | 280.1 |
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| Pc Abs | Corr | ļ | 301.0 | | 300.5 | | 300.5 | | 300-0 | | 299.5 |
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Sheet 1 of 3

| Test Item SN | 1 Test No. 10- 78 t | hru LD- 83 Test Item | SRLD | |
|----------------|---------------------|----------------------|------------|--|
| Date | November 1, 1960 | Work Order | 2228-025 | |
| Test. Engineer | L. P. Sileo | Test Facility | <u>W-1</u> | |

TEST:

Gas Generator Assembly

PURPOSE :

Reliability testing of the gas generator assembly.

HEMARINE

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No noticeable drop in nozzle pressure was recorded (30-second duration firings).

DATA RECORDED ON: Speedomax

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| TEST NC. | | T.D- 78 | | LD- 79 | | I.D. 80 | | I.D. 81 | | 1.D_ 82 | |
| DURATION SOC | | 30.9 | | 30.5 | | 31.0 | | 30.5 | | 30.6 | |
| EDURAT | TIN see | 2340 | •0 | 2370 | •5 | 2401. | 5 | 2432 | .0 | 2462 | 6 |
| TIMEC | T DATA | Static | 30.4 | Static | 30.0 | Static | 30.5 | Static | 30.0 | Static | 30.1 |
| | | | | | | | | | - 0.0 | | |
| LNP . | psig | | 287 | | 285 | | 288 | | 288 | | 288 |
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| FLP | psig | | 112 | | 113 | | 111 | | LIL | · | 117 |
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| LP | psig | 533 | 433 | 538 | 436 | 540 | 137 | 537 | 137 | 536 | 437 |
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| TP | psig | 538 | 490 | 542 | 496 | 543 | 494 | 541 | 495 | 540 | 1194 |
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| | <u>, psi</u> | | 30.2 | ļ | 30.0 | | 30.5 | | 30.9 | | 30.0 |
| W | 12/120 | | 0 33 | | 0 31 | | 0 1 | | 0.25 | ····· | 0.20 |
| <u>├</u> | 10/ 860 | | 2.25 | | 2.24 | | 2.34 | | 6.22 | | 2032 |
| LNT | OF | | 1262 | <u>├</u> | 1252 | | 1256 | | 1250 | | 7216 |
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| GOT | 0 _F | | 1393 | | 1375 | | 1374 | | 1380 | | 1362 |
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| FLT | v | | | | | | | - | | | |
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| | <u> </u> | | 282.3 | ļ | 284.2 | | 283.7 | | 283.7 | Į | 283.7 |
| | | | 707 5 | ļ | | | 101 0 | | | | 100.0 |
| 180 | 800 | | 121.2_ | | 121.4 | | 124.2 | · | <u>µ20.7</u> | | 122.3 |
| Wearn | lb/sec | | 2.32 | | 2.33 | h | 2.32 | | 2.33 | ļ | 2.29 |
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| Fcorr | 10 | | 282.3 | | 284.2 | | 283.7 | | 281.8 | | 280.4 |
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| Pc Abs | Corr | | 300.5 | L | 302.0 | | 301.0 | ļ | 101.0 | | 299.5 |
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Sheet 3 of 3

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| Fcorr | 1b | | 279.5 | | | | | | | | |
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| Pc Ab | s Corr | | 298.5 | ╉───── | ļ | | | | ļ | | |
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ROCKET LABORATORY PRELIMINARY TEST REPORT

Sneet 1 of 2

| Test Item SN | 1 Test 30. LD- 84 thru LD- | Test Item | SRED |
|---------------|----------------------------|---------------|------------|
| Date | November 2, 1960 | Work Order | 2228-025 |
| Test Engineer | L. Goldschlag, 1st Shift | Test Facility | <u>W-1</u> |

TEST :

1.1

Gas Generator Assembly.

PURPOSE:

Reliability testing of the gas generator assembly and observing heat transfer characteristics of the liquid between the gas generator and the throttle valve.

REMARKS :

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The propellant feed temperature was recorded between each burst and after the last burst for about 15 minutes. The line was not purged after each burst.

Three ten-second full thrust firings with 3 minutes between the start of each burst.

DATA RECORDED ON: Spe

Speedomax

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CELL W-1

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Sheet 2 of 2

| At = . | 7040 1n ² | | Tes | t No. I | .D- 8)+# | to ID | <u>- (3-1(</u> |) Sucon | d Burst | ;;;) * | |
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| LNP | psig | | 286 | <u></u> | 288 | | 289 | | | | |
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| RNP | psig | | 286 | | 288 | | 288 | | | | |
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| 1.0.0 | barg | | 291 | | 295 | | 294 | | | | |
| FLP | psig | | 115 | | 117 | | 119 | | | | |
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| TP | psig | 543 | 495 | 547 | 502 | _550 | 503 | | · | | |
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| W | 1b/sec | | 2.33 | | 2.34 | | 2.35 | | | | |
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| Isp | 880 | | 121.0 | | 121.2 | | 120.9 | | | | |
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ROCKET LABORATORY PRELIMINARY TEST REPORT

Sheet 1 of 2

| Test : | Item SN | 1 Test No. LD- 85 thru L | D- 88 Test Item | SRLD |
|--------|---------|--------------------------|-----------------|------------|
| | Date | November 2, 1960 | Work Order | 2228-025 |
| Test B | ngineer | L. Goldschlag, 1st Shift | Test Facility | <u>₩-1</u> |

TEST:

Gas Generator Assembly.

PURPOSE:

Reliability testing the gas generator assembly.

REMARKS:

Run ID-85 Recorded propellant feed temperature for about 25 minutes after shutdown.

Run LD-88 Ran until tank was emptied of H_2O_2 , about 55 seconds No noticeable drop in nozzle pressure was recorded in these runs.

DATA RECORDED ON: Speedomax

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CELL W-1

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Sheet 2 of 2

| At = .7 | 2040 in~ | | Tes | t No. I | D- 85 | _ to LI | - 88 | | | | |
|--|-------------|---------|-------|----------|--------------|--------------|---------|--------|--------------------------|---------------------------------------|---|
| TEST NO | | [.] | 5- 85 | LD- | 86 | LD- | 87 | LD- | 88 | I,D | - 88 |
| DURATIC | N Sec | 29 | •4 | 29, | 2 | | 3 | 46. | 0 | | والمحمد والم |
| EDURATI | CN sec | 255 | 3.9 | 2583 | .8 | 2614 | .1 | | والمراجع المراجع المراجع | 2660 |).1 |
| TIME OF | F DATA | Static | 28.9 | Static | 29.4 | Statio | 29.8 | Static | 30.0 | Static | 15.5 |
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| LNP | psig | | 287 | | 285 | | 286 | | 2.86 | | 286 |
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| RNP | psig | | 288 | | 284 | | 285 | | 286 | | 286 |
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| COP | psig | | 293 | | 290 | | 290 | | 290 | | 291 |
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| FLP | p81g | | 44.5 | | 444 | | 412 | | 412 | | 412 |
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| LP | peig | 530 | 490 | 534 | 434 | 537 | 434 | 535 | 434 | | <u></u> |
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| UNCLASSIFIED UNCLASSIFIED 1. Manued Rocket Lift Davize. 2. Contract No. 2. Contract No. | | | |
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| AD Accession No- Beli Aerosystems Company Division of Bell Aerospace Corporefon Buffalo 5, New York, SMML ROCKET LIFT DE- VICE - PHASE I DESIGN, FABRICATION, AND STATIC TESTING. W.F. MOORE, J. EROAL, J. BUNGESS, S. CZANECKI. | Report No. TEEC IR 61-45 . March 1961145pp. (Contract Dak4-177-TC-642) USATRECOM Froj 9838-11-009-14, ST Unclassified Report. The design of a manned mmail rocket lift de- vice is described. A stability and control analysis is presented with recommendations. Compenent development is described. Test (ever) | data including reliability determinations on component and system levels is presented. Results indicate the system is mitable for manned flight testing. Recommendations are usede to proceed immediately with hot system firings and manned flight testing. | |
| UNCLASSIFIED UNCLASSIFIED I. Kanned Rocket Lifft Device. 2. Contract No. DA44-177-TC-642 | CINCLASS LFTED | UNCLASSIFIED | DIKCEASSTETED |
| AD Accession No. AD Accession No. Bell Aerosystems Company Division of Bell Aerospace Corporation Buffalo 5, New York, SMALL ROCKET LIFT DE- VICE - FHASE I DESIGN, FABRICATION, AND STATIC TESTING. W.F. MOORE, J. REOMI, J. BURGESS, S. CZARWECKI. | Report No. TREC TR 61-45 March 1961143pp. (Contract DA44-17)-TC-642) USATRECOM Froj 9838-11-009-14, ST Unclassified Report. The design of a manned small ro-ket lift de- vice is described. A stability and control analysis is presented with recommendations. Component development is described. Test (over) | data including reliability determinations on component and system levels is presented. Results indicate the system is suitable for manned flight testing. Recommendations are made to proceed immediately with hot system firings and manned flight testing. | |

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| UNCLASSIFIED UNCLASSIFIED 1. Manued Rocket Lift Device. David-175-TC-642 | | CELLAI SSAFTED AND | - UNCLASSIFIED |
| AD Accession No. Beli Aerosystems Company Division of Bell Aerospace Carporétion Buffalo 5, New York, 2001L MOCHET'LIFT DE- VICE - FHASE I DESIGH, AABRICATION, AND | STATIC TESTING. W.F. MOMEL, J. LEGUL, J. BUNGESS, S. CZANDEGKI. Report No. TICC IE 61-45 March 196114500 (Contract DA44-177-TC-642) USATECOM Froj 9238-11-009-14. ST Unclassified Report. The design of a manued small rocket lift de- vice is described. A stability and control analysis is presented with recommundations. Component development is described. Test (ever) | data including reliability detorminations on component and system levels is presented. Results indicate the system is suitable for memed flight testing. Recommendations are made to proceed immediately with hot system firings and memmed flight testing. | |
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| AD Accession No. Beil Acrosystems Company Division of Beil Acrospace Corporation Difialo 5, Her Tork, SMAIL ROCKET LIFT DE- VICE - FMASE I DESGER, FABRICATION, AND | STATIC TESTING. W.F. MORE, J. REGLI, J. BURGESS, S. CZARDECKI. Report No. TREC IN 61-65 . March 1961 145p. (Contract Davi-177-TC-642) USATRECOM Proj <u>919-11-009-14</u> , STUnclassified Report. The design of a manuel small roshet lift de- vice is described. A stability and control analysis is presented with recommendations. Component development is described. Test (ever) | data including reliability determinations on component and system levels is presented. Results indicate the system is suitable for manned flight testing. Recommendations are made to proceed immediately with hot system firings and manned flight testing. | |

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