# DEVELOPMENT OF A NASA STANDARD GAS GENERATOR

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# DEVELOPMENT OF A NASA STANDARD GAS GENERATOR

- GOALS
- BACKGROUND
- APPROACH
- FEASIBILITY STUDY RESULTS
- FEASIBILITY STUDY CONCLUSIONS
- FUTURE PLANS

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This shows the outline of the presentation.

# NSGG GOALS

- DESIGN, DEVELOP, AND QUALIFY A NASA STANDARD GAS GENERATOR
  - SAME ENVELOPE AS NASA STANDARD INITIATOR (NSI)
  - HIGH THERMAL, VACUUM AND AGE STABILITY
  - CONSISTENT, RAPID-DELIVERY, GAS PRODUCTION
  - CAPITALIZE ON NSI QUALIFICATION
    - + MAINTAIN STRUCTURE AND ELECTRICAL IGNITION INTERFACE
    - + MODIFY PYROTECHNIC LOAD
    - + CONDUCT DELTA-QUALIFICATION
- CHARACTERIZE OUTPUT PERFORMANCE FOR A VARIETY OF APPLICATIONS
- MAKE NASA STANDARD GAS GENERATOR GFE, LIKE NSI

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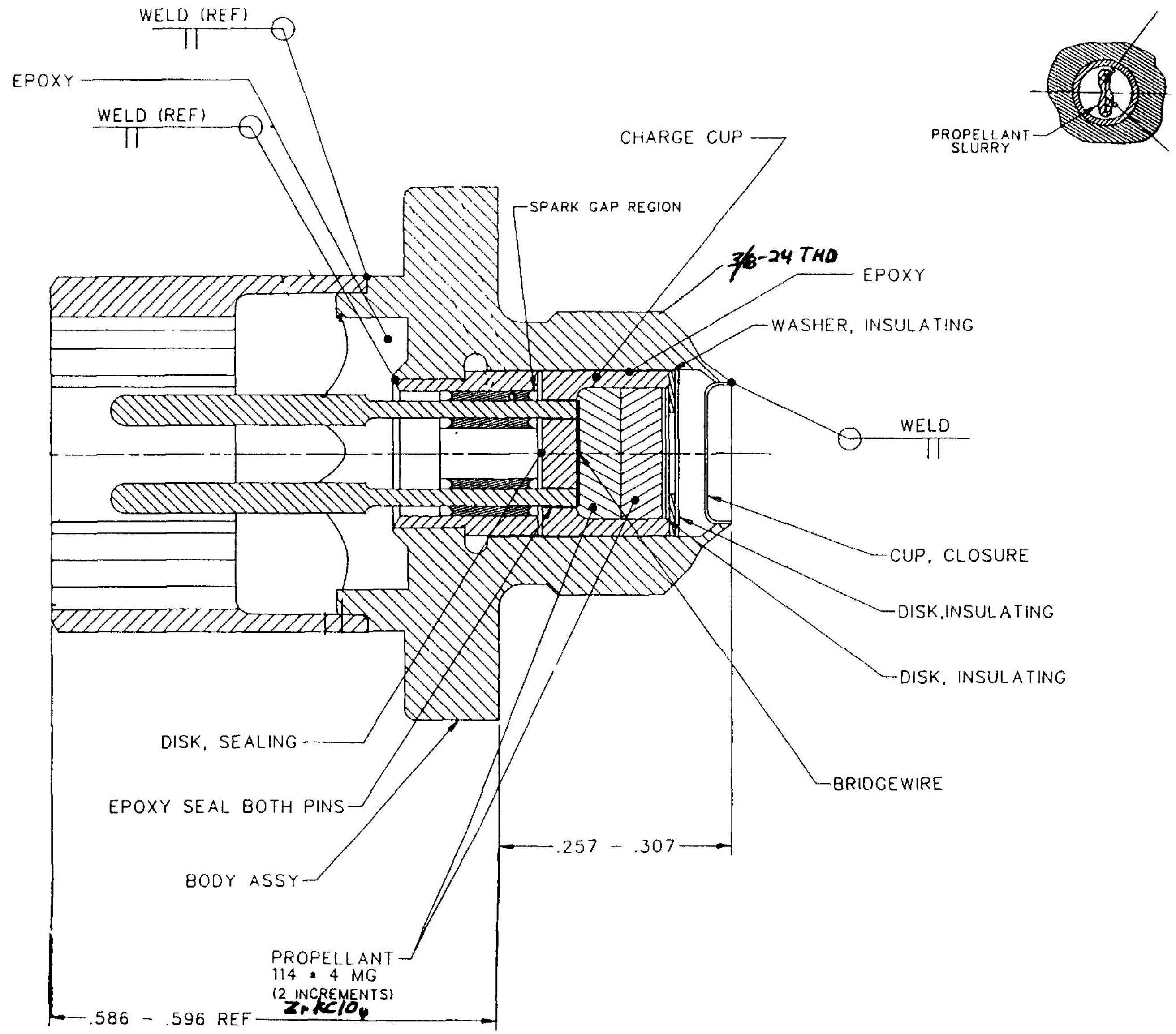
The NSGG goals are to create a NASA standard gas generating cartridge, characterize its performance and make it readily available to users. A cartridge within the same envelope as the NASA Standard Initiator (NSI) has the greatest potential use, as described in subsequent viewgraphs. Due to long-term, deep-space operations, the materials selected must withstand temperatures of over 300 F at vacuum, while exhibiting long-term stability. Consistent performance in gas production is necessary in work applications, with rapid delivery rates to accommodate small pyrotechnic mechanisms. The qualified NSI will be minimally modified to maintain the existing structure and electrical ignition interface. The approach is to replace up to 50 % of the current NSI output charge with a gas generating material, which will require only a delta qualification, rather than a complete verification of performance and environmental exposure. The output of the NSGG will be measured and characterized with a variety of mechanical applications. Ultimately, the NSGG will be available as Government-furnished equipment, like the NSI.

# NASA STANDARD INITIATOR (NSI)



This is a cross section of the NSI to show the structure and proposed change. Only the second increment of the main ZrKCLO4 will be modified.

# BACKGROUND

- NSI HAS BEEN MISAPPLIED AS A GAS GENERATING CARTRIDGE
  - DESIGNED AND INTENDED TO BE AN INITIATOR
  - CONVENIENT SIZE/ENVELOPE
  - QUALIFICATION STATUS
  - NASA PREFERENCE; APPLICATION AS INITIATOR ON SHUTTLE PAYLOADS
  - INADEQUATE DESIGN/DEVELOPMENT GUIDELINES FOR GAS GENERATOR APPLICATIONS
  - COMBUSTION/GAS GENERATING SENSITIVITIES/ VARIATIONS

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Although the NSI was designed as an initiator, it has been misapplied as a gas generating cartridge. It's convenient, small size and envelope has allowed it to be installed in a variety of small pyrotechnic mechanisms. It's qualification status allows ready acceptance by spacecraft designers and the Government. In fact, the Shuttle payload document states that the NSI shall be used as the electrical ignition interface, or an alternate approach justified; an equivalent safety performance and qualification demonstration is expected.

Unfortunately, design/development guidelines for gas generating cartridge applications are inadequate in providing assurance of successful performance. Furthermore, the NSI gas generating output performance is sensitive to the conditions under which it is fired, such as initial volume and configuration, materials and volume change as in a stroking piston.

# BACKGROUND (Continued)

- SEARCHED FOR A QUALIFIED GAS GENERATING CARTRIDGE
  - MANY CARTRIDGES CONTAINED THE SAME PYROTECHNIC COMPOSITION AS THE NSI
  - THE MODIFIED CARTRIDGES DO NOT MEET NASA ENVIRONMENTAL REQUIREMENTS
  - OUTPUT PERFORMANCES NOT ADEQUATELY CHARACTERIZED
  - NO OTHER CARTRIDGE HAS NSI ACCEPTANCE AND HISTORY

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Industry was surveyed for a gas generating cartridge that met the above requirements. Many cartridges contained the same pyrotechnic composition as the NSI, and the modified cartridges did not meet the thermal/vacuum stability. Hercules Hi Temp was frequently used, which contains a high percentage of RDX that will sublime under vacuum. Again, the output performances of these cartridges were not characterized, so there was no need begin such an evaluation over an NSI-derived cartridge. Finally, no other cartridge has achieved the NSI recognition, acceptance and variety of applications.

# APPROACH FOR NSGG DEVELOPMENT/QUALIFICATION

- DEVELOP EVALUATION TEST METHODS
- CONDUCT FEASIBILITY STUDY
- CONDUCT PRELIMINARY DEVELOPMENT
- CONDUCT FINAL DEVELOPMENT
- CONDUCT DELTA-QUALIFICATION

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Our approach for NSGG development and qualification was planned to be conducted in several phases. Test methods were developed to evaluate output performance for a variety of potential applications. A feasibility study using modified NSIs was accomplished. Preliminary and final development will be conducted with a delta qualification to evaluate the effects of manufacturing lots and environments.

# CHARACTERIZATION OF NSGG OUTPUT

- OUTPUT OF ANY PYROTECHNIC CARTRIDGE DEPENDS ON HOW IT IS APPLIED
- WHY FOUR OUTPUT TEST METHODS?
  - CLOSED BOMB (10 CC)
    * UNIVERSALLY ACCEPTED STANDARD
    * DOES NOT SIMULATE ANY PYROTECHNIC DEVICE
  - DYNAMIC TEST DEVICE
    * SIMULATES AN EJECTOR
  - MCDONNELL ENERGY SENSOR
    * SIMULATES THRUSTER ACTING AGAINST A CONSTANT RESISTANCE
  - HALOE PIN PULLER
    * SIMULATES A RETRACTOR

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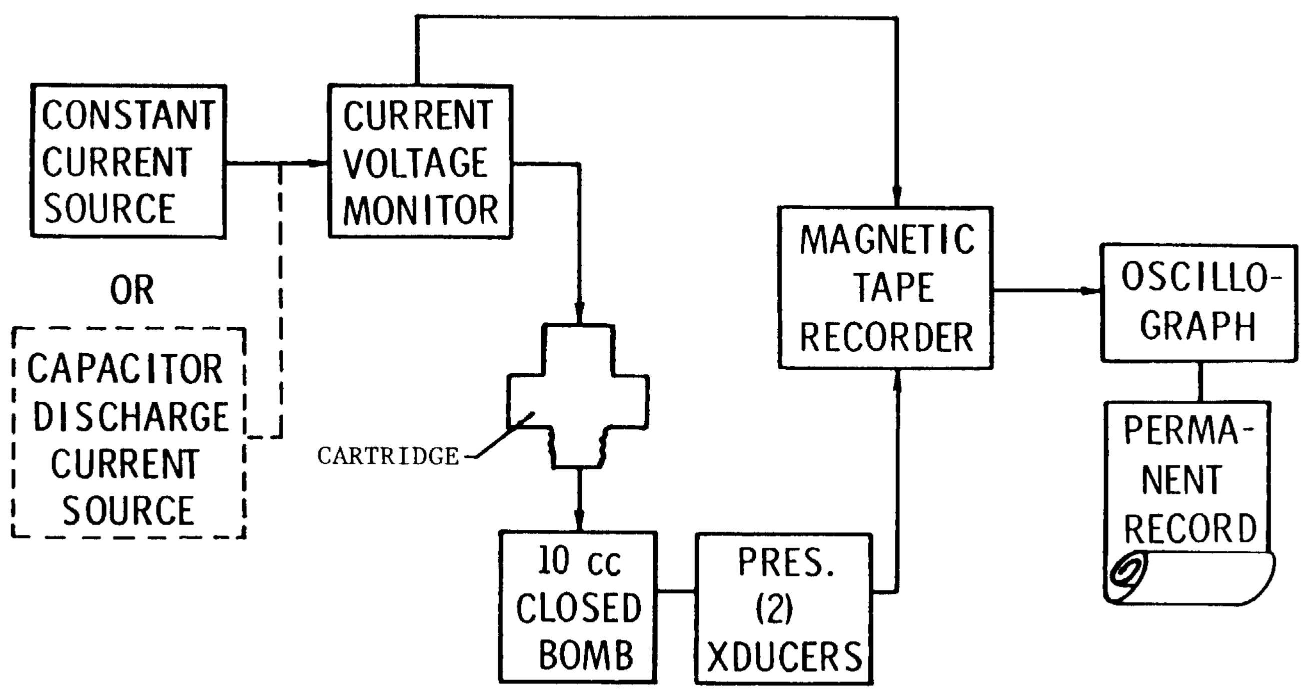
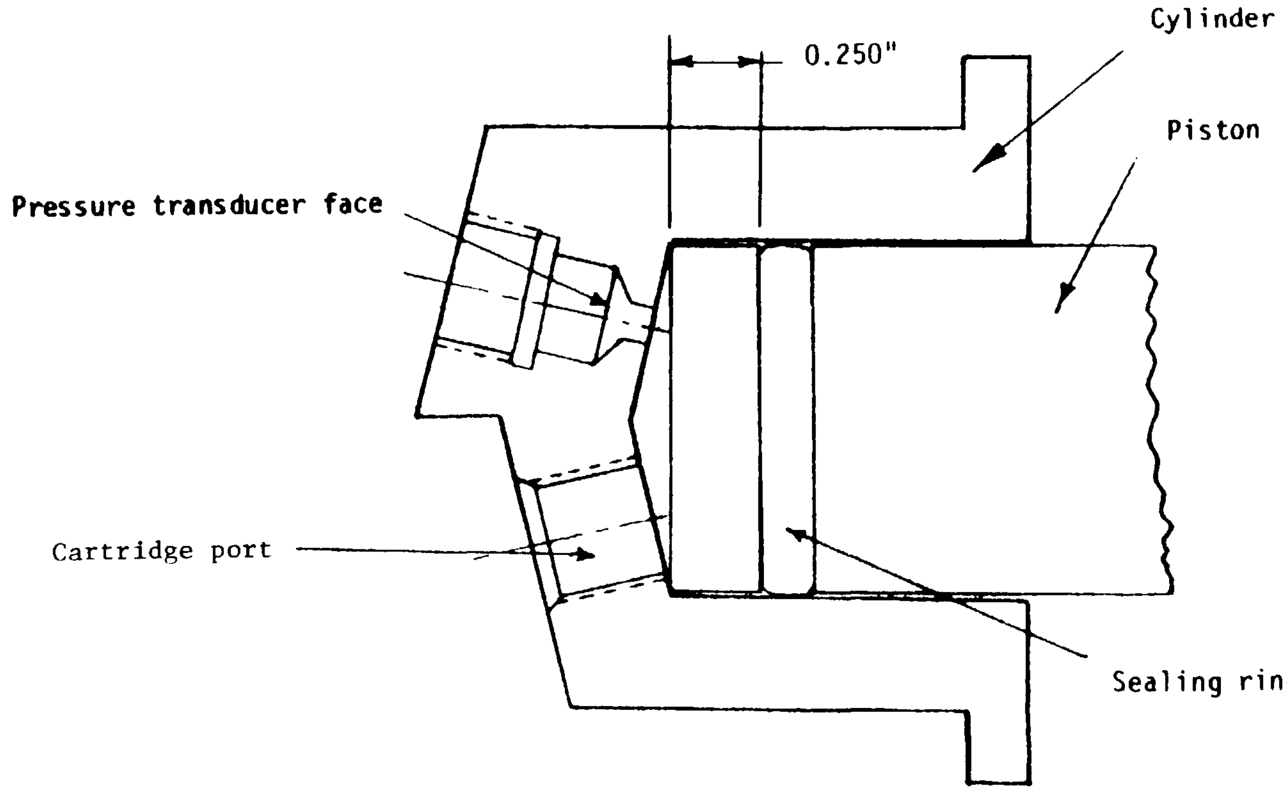
The output of any pyrotechnic cartridge depends on how it is applied. Therefore, the output of the NSGG should be evaluated with a variety of applications. Four test methods, fabricated of steel for reusability, were selected for functional evaluation for the following reasons. The 10 cc closed bomb, described in figure 8, is the universal performance standard for acceptance and design of cartridges and applications in devices. However, this test does not simulate any pyrotechnic device; a pressure trace achieved within a fixed volume has no meaning in what work a cartridge could accomplish in a mechanism. The Dynamic Test Device, shown in figure 9 is a one-inch diameter, one pound, one-inch stroke piston/cylinder device which simulates an ejector with a free mass. The energy delivered by the cartridge is obtained by measuring the final velocity of the mass ($1/2mv^2$). The McDonnell Energy Sensor (figure 10) has a half-inch diameter piston which strokes against a constant resistance force, provided by 300 pound-strength, crushable honeycomb, to simulate a thruster. The energy delivered by the cartridge is obtained by multiplying the stroke achieved in inches by the strength of the honeycomb in pounds force to obtain a value in inch-pounds. The HALOE pin puller, shown in figure 11, has a 0.4-inch diameter piston which strokes to withdraw a pin. Energy measurements are achieved by measuring the amount of crush of the energy absorbing cup at the end of the piston stroke. This cup crush has been calibrated in inch-pounds of energy through dynamic impact tests to drive the piston through its stroke.

Each of the energy measuring devices represents a unique mechanical aspect of pyrotechnic devices in terms of the mass moved, the resistive forces and the transfer of energy from the cartridge. The Dynamic Test Device has a very large surface area and mass of the stroking piston. The McDonnell Energy Sensor presents the minimum possible initial free volume and measures work on the axis of the cartridge, since the output of cartridges is directional. The HALOE pin puller presents a tortuous, energy-absorbing path for the gas output of the cartridge to vent through a 0.1-inch diameter opening to drive the small-mass piston. The NSGG data collected in these devices will provide guidelines for potential users. The user would compare his intended application mechanism to the above three test methods and have a starting point to begin his design. It must be emphasized that the user would have to demonstrate the performance of the NSGG in his application, rather than imply that the energy measured in the three test methods will assure successful performance.

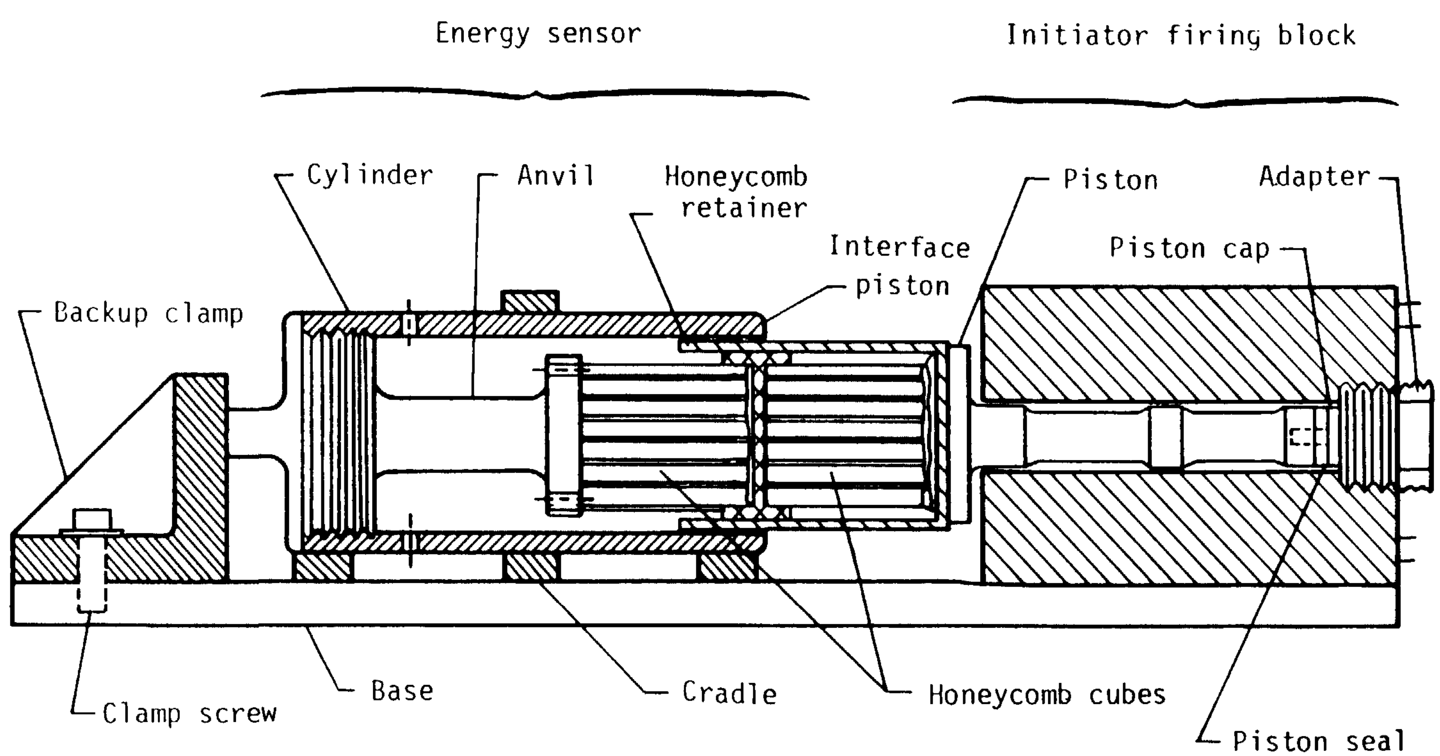
## CLOSED BOMB FIRING AND MONITORING SYSTEM



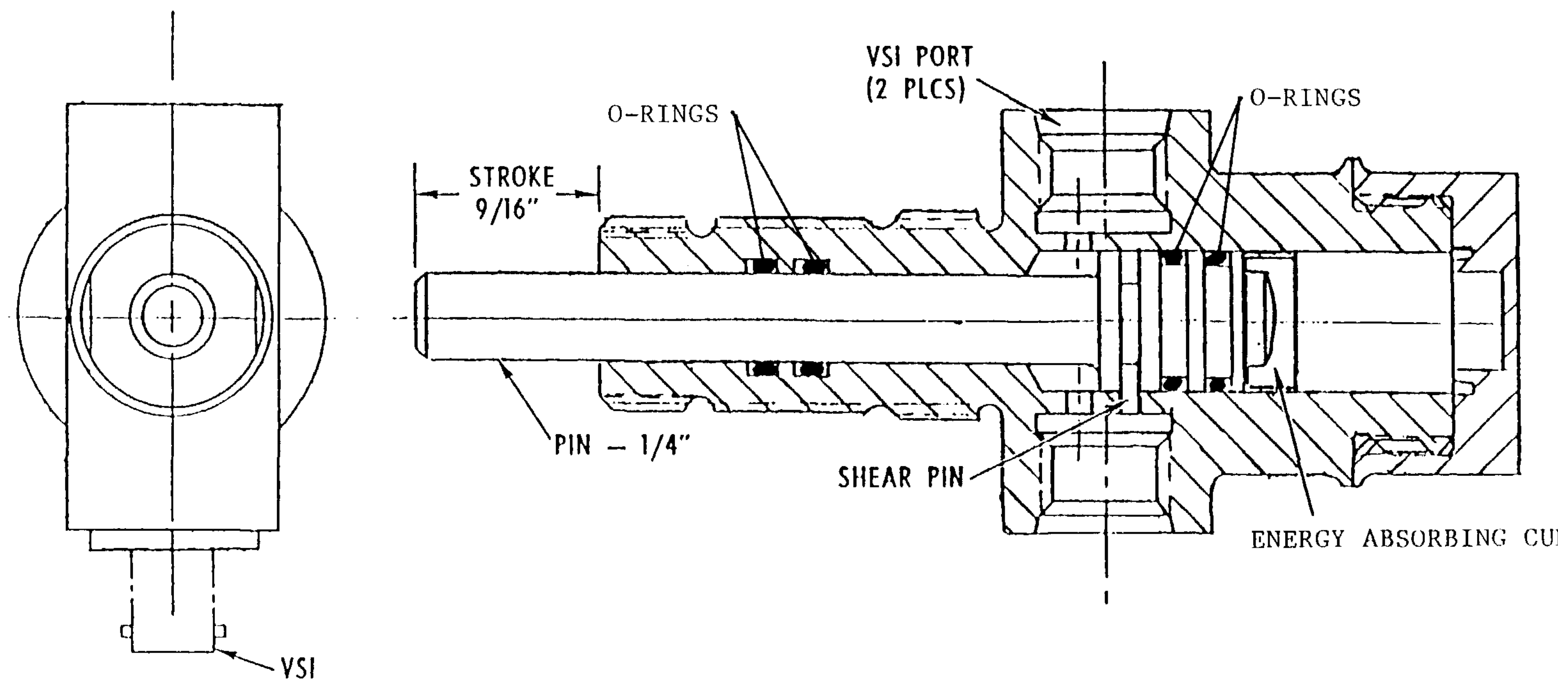
# NASA LARC DYNAMIC TEST DEVICE



# MCDONNELL ENERGY OUTPUT TEST FIXTURE



# Viking PYRO OPERATED PIN PULLER — 1/4"



# FEASIBILITY STUDY GOALS

- EVALUATE TEST METHODS/PERFORMANCE CRITERIA
- DEMONSTRATE FEASIBILITY OF ENERGY PRODUCTION WITH MODIFIED NSI WHICH INCLUDES GAS GENERATING MATERIAL

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The goals of the feasibility study were to evaluate the proposed test methods, as well as to establish a performance criteria for what could be expected from an NSGG. Also, demonstrate the feasibility of modifying the NASA Standard Initiator with the addition of gas generating material. These goals have been demonstrated, as described in subsequent viewgraphs, to provide the confidence needed to proceed into development.

# TEST METHODS DEMONSTRATION

- VIKING STANDARD INITIATOR (VSI)
- VSI WITH 20 MG BKNO3, BONDED EXTERNALLY

# GAS GENERATING MATERIALS EVALUATION

- NSI WITH STANDARD 114 MG MIX
- NSI WITH 85 MG STD. MIX AND 30 MG BKNO3 (25 PERCENT)
- NSI WITH 85 MG STD. MIX AND 30 MG HI TEMP (25 PERCENT)
- NSI WITH 85 MG STD. MIX AND 30 MG HI SHEAR 006 (25 PERCENT)
- NSI WITH 57 MG STD. MIX AND 57 MG HI SHEAR 006 (50 PERCENT)

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The feasibility study was divided into two areas, test method demonstration and gas generating materials evaluation.

Two different cartridge configurations were employed to evaluate the test methods. The Viking Standard Initiator (VSI) is a clone of the NSI, having the same housing, electrical interface and pyrotechnic charge. Past experience in adding 20 mg of boron, potassium nitrate ($BKNO_3$) to the output cup of the VSI has provided a considerable increase in output of the VSI in the pin puller, due to raising the internal pressure and achieving a more efficient combustion of the NSI mix. Actual data is shown in subsequent view graphs.

The gas generating materials evaluated were compared to the standard mix, which contains 114 mg of $ZrKClO_4$. The following four combinations were assembled and tested. The standard 114 mg load was reduced by 30 mg (25 %) and very fine $BKNO_3$ was pressed into place. The process was repeated for 30 mg of Hercules Hi Temp, which is an RDX-based energetic material. Hi Temp is not a candidate material, since it sublimes under vacuum; it was evaluated here because it would provide the most energy for the 30 mg weight. The proprietary Hi Shear 006 mix was added with both a 30 and 57 mg load, which is 50 % of the weight of the standard NSI load.

# FEASIBILITY STUDY TEST RESULTS
## AVERAGED OUTPUT

| CARTRIDGE | CLOSED BOMB PSI/MS TO PK | DYN TEST DEV INCH-LBS | PIN PULL HONEYCOMB INCH-LBS | PIN PULL CUPS INCH-LBS |
|---|---|---|---|---|
| TEST METHODS DEMONSTRATION | | | | |
| VSI | 646/.13 | 366 | 118 | 250 |
| VSI/BKNO3 EXT. | 909/.31 | 542 | 347 | 334 |
| GAS GENERATING MATERIALS EVALUATION | | | | |
| NSI | 660/.23 | 346 | 100 | 270 |
| NSI/BKNO3 (25 %) | 692/.33 | 418 | 157 | 233 |
| NSI/HI TEMP (25 %) | 887/.36 | 543 | 282 | 399 |
| NSI/006 (25 %) | 815/.35 | 502 | 257 | 345 |
| NSI/006 (50 %) | 880/1.00 | 506 | 234 | 330 |

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This chart summarizes the feasibility study test results. Each data point is an averaged value of 1 to 4 test units. The test cartridges are listed in the first column, with the Closed Bomb, Dynamic Test Device, the HALOE Pin Puller against honeycomb (instead of using the McDonnell Energy Sensor), and the HALOE Pin Puller cup crush data in the remaining columns.

For the Closed Bomb, the VSI and NSI performed within the 650 +/- 125 psi specification. A significant increase in peak pressure was achieved in each of the gas generating test configurations. Also, the times to peak pressure significantly increased. For the 50 % load, the time to peak pressure quadrupled over the NSI.

For the Dynamic Test Device, the increase in energy does not correspond to the higher peak pressure values recorded in the Closed Bomb. Furthermore, a 50 % load of the 006 mix did not significantly increase the energy delivered over the 25 % load.

For the Pin Puller against honeycomb, the low energy production of the VSI and NSI are obvious. The addition of gas generating materials increases the output by 50 to 180 %.

For the Pin Puller/cup crush configuration, the variation in output is not as dramatic as in the honeycomb configuration.

# FEASIBILITY STUDY CONCLUSIONS

- SIGNIFICANTLY MORE ENERGY DELIVERABLE WITHIN NSI ENVELOPE
- TEST METHODS VALID, USE AS PROCUREMENT STANDARDS FOR NSGG
- TEST RESULTS PROVIDE A PERFORMANCE BASELINE FOR VARIETY OF FUTURE APPLICATIONS



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At least three conclusions can be drawn from the Feasibility Study. The addition of gas generating materials provides a significantly greater delivery of energy within the NSI envelope. The test methods yield reproducible values of pressure and energy deliverable, which can be used as procurement standards for the NSGG. The test results provide a clear demonstration of the different energies produced by the three mechanisms. These results will be useful for initial predictions of performance for new pyrotechnic mechanisms, matching the new mechanism to the closest corresponding test apparatus. It is important to clarify that these test results do not reduce the responsibility of the designer to conduct a thorough test evaluation of new devices.

# CURRENT STATUS/PLANS

- AWARDED CONTRACTS FOR PRELIMINARY DEVELOPMENTAL UNITS, QUALIFIED SOURCES OF NSI
  - HI SHEAR
  - UPCO
- CONDUCT FUNCTIONAL EVALUATION WITH 4 TEST METHODS
- RECOGNIZE AND CONTROL VARIABLES

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The current status and plans for the NSGG development are summarized in three steps. Development contracts have been awarded to each of the two qualified sources of the NSI, Hi Shear and UPCO. These two companies will manufacture NSGG units, using their proprietary mixes for evaluation with the four test methods at NASA Langley Research Center. Gas generating compositions will be varied to maximize performance of the NSGG, while recognizing and controlling production variables. For example, past evaluations at Langley have indicated that the particle size of the potassium perchlorate is very influential to the efficiency of combustion and the energy produced by the NSI in the HALOE pin puller.

# FUTURE PLANS

- SELECT SUPPLIER
- MANUFACTURE FINAL DEVELOPMENTAL UNITS TO DEMONSTRATE
  - CONSISTENCY
  - EFFECTS OF TEMPERATURE/ENVIRONMENT
- MANUFACTURE 750 PRODUCTION UNITS AND CONDUCT QUALIFICATION (DUPLICATE LAST NSI DELTA QUALIFICATION
  - THREE LOTS, 250 UNITS EACH
  - ESTABLISH FUNCTIONAL PERFORMANCE STANDARDS
  - CONDUCT ENVIRONMENTAL EXPOSURES
  - FUNCTION AND COMPARE TO PERFORMANCE STANDARDS

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My future plans are to select at least one of the companies to produce Final Developmental and Qualification units. The Final Developmental units will be used to assure the consistency of performance and the effects of temperature and environments. The Qualification units will be used to duplicate the last NSI delta-qualification, which verified the NSI redesign met the -420 F functional requirement. Three lots of 250 units each will be functionally and environmentally evaluated. A portion of each group will be functioned in the four test methods "as-received" to establish a performance standard against which the environmentally exposed units will be compared.

## RESUMES

Laurence J. Bement has been employed at NASA LaRC for 28 years and has been active in pyrotechnic research, applications and failure investigations. Highlights of his career include managing the first operational in-flight helicopter escape system, service life evaluation of pyrotechnic components for military aircraft escape, and the failure investigation/resolution of the Super*Zip separation system. He has over 50 publications, including 9 patents.

Harold Karp has been active in design and manufacture of pyrotechnic devices for 28 years. He is currently director of research at Hi Shear Technology Corporation.

Morry Schimmel has 36 years of research and engineering experience in design and development of explosive, propellant and pyrotechnic devices for aerospace vehicles. He now manages his own consulting company. From 1956 to 1984 he rose to the position of Senior Pyrotechnic Staff engineer at McDonnell Douglas Corporation. Highlights of his career include engineering support for the F-111 crew module, Gemini Spacecraft, explosive transfer studies, NASA helicopter escape, B-1 seat escape system and the Super*Zip investigation. He has over 20 publications, including 11 patents.