Westinghouse
Astronuclear
Laboratory

~~CONFIDENTIAL~~

MASTER SNPO-C

WANL-TME-2763
JANUARY 1971

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced from the best available
copies to permit the broadest possible avail-
ability.

DATA ITEM S-54

LATERAL SUPPORT (U)

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

TRADE STUDY NO. 782

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

~~CONFIDENTIAL~~

MASTER

Westinghouse
Astronuclear
Laboratory

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Subcontract NP-1
CODE IDENT NO. 14683

WANL-TME-2763
JANUARY 1971

Classification cancelled (or changed to _____)
by authority of _____
by H.A.C. TIC, date SEP 11 1973

DATA ITEM S-54

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

LATERAL SUPPORT (U)

TRADE STUDY NO. 782

APPROVED BY:

F.D. Retallick
F. D. Retallick, Manager
NERVA Engineering

SPECIAL REVIEW FINAL DETERMINATION Class: <u>U</u>	Reviewers	Class.	Date
	<u>DBW</u>	<u>U</u>	<u>4-16-82</u>

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act, 1954~~

PAGE BLANK

ABSTRACT

Trade Study No. 782 was conducted in compliance with Change Order No. 70-8 to select a lateral support design approach that can be further developed for the NERVA Nuclear Subsystem (NSS) reflector assembly.

Five design approaches were evaluated by the various technical disciplines and their individual inputs were condensed into a comparison matrix that was used to select the more desirable design approach.

The evaluation of the design approaches was primarily based on the design approaches meeting the functional, technical, and non-technical requirements identified in the Reflector Assembly Specification, No. EC-677559.

Design Approach 5 (wedged seal with end-guided plungers) was selected as the design to be further developed into a lateral support system for the NSS reflector assembly. This design approach was selected because it provides the most flexibility for satisfying the launch, boost and space operational requirements defined in ECC Specification No. EC-677559. This is primarily due to the fact that it can function at higher coefficients of friction (approaching 1.0) than any of the other design approaches.

An early test of a partial length lateral support system test was recommended to provide data for input to the detailed design. A full-length vibration test accurately simulating the core restraints was recommended prior to R-1 assembly.

PAGE BLANK

INTRODUCTION

(U) This Lateral Support Trade Study contains the evaluation of five design approaches which were considered as candidate designs for the NSS lateral support system. Four of the design approaches were selected as a result of a presentation given at a meeting with SNPO-C on 11 August 1970. The presentation contained the lateral support requirements, a brief description of 30 concepts, and Westinghouse Astronuclear Laboratory (WANL) recommendations. The fifth, Design Approach 5, was developed in an effort to eliminate some of the potential problems discussed during the meeting with SNPO-C. The following list contains the design approaches and their respective drawing numbers:

<u>Design Approach</u>	<u>Description</u>	<u>Drawing No.</u>
1	Reference Design	939J733
2	Parallel Angled Seal	940J438
3	Locked Core With Control Drum Release Mechanism	939J724
4	Keyed Seal With Metal Band	939J737
5	Wedged Seal With End- Guided Plungers	929F266

(CRD) Design Approach 1 is the plunger angled-seal design that evolved from the NRX-A6 lateral support system and is being shown in the present reference design. Design Approach 2 is a parallel angle seal design with an unguided plunger that was introduced to reduce the possibility of binding of graphite components when operating in a space environment. Design Approach 3 is a two-phase lateral support system that provides a high g load capability for ground handling and launch and a lower g load capability for space operation. Design Approach 4 is a metal band concept that was conceived to eliminate possible binding and bending problems by eliminating the angled seals and plungers. Design Approach 5 is a wedged seal configuration with plungers guided only at the ends. It was

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

~~Atomic Energy Act, 1954~~

(CRD) included in the study because it contains features that reduced the possibility of plunger and seal segment binding, eliminates any significant plunger bending stress, and provides for positive inner to outer seal segment contact.

(U) The lateral support system is to be designed to comply with the requirements identified in the Reflector Assembly Specification, No. EC-677559, which forms a part of CP-677555, NERVA NSS. The purpose of the system is to laterally restrain relative motion of the core within the reflector, center the core within the reflector, and provide a mechanical bundling force upon the core elements. The system must also be capable of accommodating the relative motion of the core and reflector due to temperature and pressure during all phases of operation.

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

~~Atomic Energy Act, 1954~~

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
	INTRODUCTION	v
1.0	IDENTIFICATION OF REQUIREMENTS FOR TRADE OFF	1-1
1.1	FUNCTION	1-1
1.2	SCOPE	1-1
1.3	REQUIREMENTS	1-1
	1.3.1 Functional Requirements	1-2
	1.3.1.1 Lateral Support Function	1-2
	1.3.1.2 Core Bundling Function	1-2
	1.3.1.3 Lateral Support Seal Flow	1-3
	1.3.1.4 Reliability	1-3
	1.3.1.5 Safety	1-3
	1.3.2 Technical Requirements	1-3
	1.3.2.1 Interface Requirement	1-4
	1.3.2.2 Weight	1-4
	1.3.3 Non-Technical Requirements	1-4
	1.3.3.1 Development and Qualification	1-4
	1.3.3.2 Schedule	1-4
2.0	DESCRIPTION OF DESIGN APPROACHES	2-1
2.1	DESIGN APPROACH 1 (REFERENCE DESIGN)	2-7
2.2	DESIGN APPROACH 2 (PARALLEL ANGLE SEAL)	2-13
2.3	DESIGN APPROACH 3 (LOCKED CORE WITH CONTROL DRUM RELEASE MECHANISM)	2-17

TABLE OF CONTENTS (CONTINUED)

<u>Section</u>		<u>Page</u>
	2.4 DESIGN APPROACH 4 (KEYED SEAL WITH METAL BAND)	2-27
	2.5 DESIGN APPROACH 5 (WEDGED SEAL WITH END GUIDED PLUNGERS)	2-33
3.0	COMPARISON MATRIX	3-1
4.0	SELECTION OF DESIGN	4-1
	REFERENCES	4-4

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
2-0	Lateral Support Envelope	2-3
2-0A	Summary of Lateral Support Design Approaches	2-4
2-1	List of Materials (939J733)	2-8
2-1	Reflector, Aluminum Structure (939J733)	2-9
2-1A	Design Approach 1 (Reference Design)	2-11
2-2	List of Materials (940J438)	2-14
2-2	Parallel Angled Seals, Lateral Support (940J438)	2-15
2-2A	Design Approach 2 (Parallel Angle Seal)	2-16
2-3	List of Materials (939J724)	2-18
2-3	Locked Core With Control Drum Release Mechanism (939J724)	2-19
2-3A	Design Approach 3 (Locked Core With Control Drum Release Mechanism)	2-20
2-3B	Design Approach 3 (Locked Core With Control Drum Release Mechanism)	2-22
2-3C	Design Approach 3 (Locked Core With Control Drum Release Mechanism)	2-24
2-4A	Key Principle	2-27
2-4	List of Materials (939J737)	2-28
2-4	Keyed Seal With Metal Bands, Lateral Support (939J737)	2-29
2-4B	Design Approach 4 (Keyed Seal With Metal Band)	2-31
2-5	List of Materials (929F266)	2-34
2-5	Wedged Seal With End-Guided Plungers, Lateral Support (929F266)	2-35
2-5A	Design Approach 5 (Wedged Seal With End Guided Plungers)	2-37

LIST OF TABLES

<u>Table</u>		<u>Page</u>
2-1	Components Common to the Various Lateral Support Design Approaches	2-5
2-2	Development Tests Used in Support of Trade Study No. 778	2-6
3-1	Reliability and Safety Considerations	3-3
3-2	Performance Considerations	3-4
3-3	Performance Considerations	3-5
3-4	Performance Considerations	3-6
3-5	Performance Considerations	3-7
3-6	Weight Considerations	3-8
3-7	Development & Qualification Considerations	3-9
3-8	Schedule Considerations	3-10
3-9	Matrix Summary	3-11

(U) 1.0 IDENTIFICATION OF REQUIREMENTS FOR TRADE-OFF

1.1 FUNCTION

(CRD) The function of the lateral support system is to laterally restrain motion of the core relative to the reflector, center the core within the reflector, and provide mechanical bundling force to the core elements. The lateral support system also provides a method for controlling coolant flow aft between the core and the reflector support structure. The system, while performing the above functions, must be capable of accommodating the relative motion between the reflector support structure and the core due to temperature and pressure changes during all phases of operation.

1.2 SCOPE

This entry in the trade study identifies the functional, technical, and non-technical requirements for the group of components called the lateral support system. The functional and technical requirements are quoted from the reflector assembly specification No. EC-677559 and where necessary are supplemented by interpretations in terms of specific physical properties. Requirements of specification No. EC-677559 not quoted in this section are assumed to be satisfied equally by all design approaches or are of a basic, non-tradeable type that all design approaches must and do meet. Following the functional and technical requirements are requirements which the design approaches must meet in order to satisfy contract schedules.

1.3 REQUIREMENTS

(U) This section presents the requirements that were used to evaluate the design approaches. The paragraphs enclosed by quotation marks are the lateral support requirements obtained from Section 3.0 of the Reflector Assembly Specification No. EC-677559. The information following these paragraphs contains the working data that were used when the appropriate EC specification values were to be determined (TBD).

1.3.1 Functional Requirements

(CRD) 1.3.1.1. Lateral Support Function

"3.1.1.1.3.1.2.2 Lateral Support Function. - The RA shall provide lateral support to the reactor core. The requirements on this lateral support function are as follows:

- (a) Prevent core components from separating.
- (b) Prevent the core from impacting the reflector due to relative lateral motion between the core and the reflector for lateral loads up to (tbd) g at frequencies ≥ 6 Hz prior to and through the launch boost phase and lateral loads up to (tbd) g at (tbd) Hz or greater subsequent to the boost phase.
- (e) The integrity of the lateral support capability shall be maintained with a core radial thermal expansion of 1.8 percent from the as-assembled dimensions."

(CRD) The lateral support system shall prevent the core from impacting the reflector for lateral loads up to 3 g prior to and through the launch boost phase and lateral loads up to 1.5 g at 6-500 Hz subsequent to the boost phase as specified in (b) above.

(CRD) 1.3.1.2 Core Bundling Function

"3.1.1.1.3.1.2.3 Core Bundling Function. - To satisfy the lateral support function, the RA shall include the means to provide a radially inward pneumatic load on the core during all operating conditions. The pneumatic bundling force shall be equivalent to an average pressure

(CRD) of (tbd) psi. In addition, at assembly the RA shall provide a mechanical bundling force at the Core Periphery surface. This force shall be equivalent to an average pressure of 10 psi over the forward one-seventh of the core and (tbd) psi over the aft six-sevenths of the core."

(CRD) For the purpose of this trade study, a mechanical bundling pressure of 2.5 psi was assumed for the aft six-seventh length of the core. The minimum pneumatic pressure was assumed to be 2.0 psi. These assumptions are consistent with the values used in DRM 53622, Core Bundling Pressure Optimization, prepared concurrently with this document.

(U) 1.3.1.3 Lateral Support Seal Flow

"3.1.1.1.3.1.3.4 Lateral Support Seal Flow. - The RA shall be designed to limit the axial coolant flow bypassing the core to (tbd) $\pm$ (tbd) lb/sec while operated at Rated Performance."

(U) Limit the axial coolant flow bypassing the core to 0.63 ± 0.09 lb/sec. This value is based on the coolant flow required to adequately cool the components in the lateral support region of the reference design.

(U) 1.3.1.4 Reliability

"3.1.2.1 Reliability. - The reliability allocation for the RA is 0.999839."

(U) 1.3.1.5 Safety

"3.1.2.7 Safety. - The RA shall conform to the requirements of 3.1.2.7 (Safety) of CP-677555."

1.3.2 Technical Requirements

(U) 1.3.2.1 Interface Requirement

"3.2.1 Interface Requirements. - Functional, dimensional, physical, and procedural interactions between the RA and the other Engineering Critical Components which comprise the NSS, as defined in 3.2.2.2 (Engineering Critical Components List) of CP-677555 shall not degrade performance below that specified in 3.1 (Performance) of CP-677555 and its Engineering Critical Components."

(CRD) 1.3.2.2 Weight

"3.3.1.2 Weight. - The target weight for the RA is 3,750 pounds."

1.3.3 Non-Technical Requirements

(U) 1.3.3.1 Development and Qualification

The development and qualification effort is to be compatible with contractual commitments. Available technology and materials should be utilized whenever possible to reduce development time and cost.

(U) 1.3.3.2 Schedule

The time required for development, production, and assembly of the lateral support system shall be compatible with R-1 Test date of October 15, 1973.

CONFIDENTIAL

RESTRICTED DATA

Atomic Energy Establishment
Cairo

2.0 DESCRIPTION OF DESIGN APPROACHES

- (U) The objective of each lateral support design approach evaluated in this trade study is to comply with the requirements defined in the Reflector Assembly Specification, No. EC-677559. An attempt has been made to include features in the design approaches that can be further developed to eliminate any possible binding or lockup problems that are associated with high graphite friction in a hard vacuum environment.
- (U) The reflector, lateral support, and core dimensions, as shown in Figure 2-0, are the constraining dimensions used in the design approaches. The radial dimensions are as established in the NSS Radial Dimension Optimization Study, WANL-TME-2707.
- (CRD) The core diameter of 38.951 is the as-assembled dimension for a graphite fuel or composite fuel core. This includes a core periphery which is discussed in full detail in the Core Periphery Trade Study, No. 778.
- (CRD) The radial gap of 1.639 inches between the core periphery and the reflector support structure is based upon the expansion of the composite core and the contraction of the aluminum support structure. The gap size includes considerations for actual tolerances expected on the manufactured components and thermal effects.
- (U) The compression spring size is restricted to 1.237 inch outside diameter and a maximum as-assembled length of 3.200. This length is determined by the total plunger travel required and the envelope available between the O. D. of the reflector support structure and the reflector O. D.
- (U) The 54.000 reflector O. D. was established by optimizing the radial dimensions of the core, lateral support system, and reflector. This is covered in detail in the Radial Dimension Optimization Study, WANL-TME-2707.
- (U) All design approaches are based on utilizing a reflector which has an aluminum support structure with beryllium segments fastened to it. The reflector design features were presented in the Reflector Assembly Trade Study, No. 763, WANL-TME-2673. A summary of the five lateral support design approaches is shown in Figure 2-0A. Table 2-1 provides a cross-reference matrix for comparing the components that are common to the various designs.

CONFIDENTIAL

RESTRICTED DATA

ATOMIC ENERGY ESTABLISHMENT, CAIRO

~~CONFIDENTIAL~~

(THIS PAGE IS UNCLASSIFIED)

The description of each design approach contains a brief narration on how the design approach evolved and a detailed description of the various components in the design approach. Layout drawings have been included to show how the lateral support design approach interfaces with the other NSS components. The list of materials provides a quick reference as to the materials used in the various components. Table 2-2 provides a list of development tests used in support of developing and evaluating the lateral support design approaches.

~~CONFIDENTIAL~~

Reflector, Lateral Support And Core As Assembled

Figure 2-0. Lateral Support Envelope

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

Figure 2-0A. Summary of Lateral Support Design Approaches

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

TABLE 2-1
COMPONENTS COMMON TO THE VARIOUS
LATERAL SUPPORT DESIGN APPROACHES

Component	Design Approaches				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Inner Seal Segment	X	X	X	X	X
Outer Seal Segment	X	X	X	X	X
Insulation	X	X	X	X	X
Plunger	X	X	X		X
Segment Retainer	X	X	X	X	X
Sleeve	X	X	X		X
Capsule	X	X	X		X
Capsule Seal	X	X	X		X
Cap	X	X	X		X
Cap Seal	X	X	X		X
Spring	X	X	X		X
Plunger Sleeve		X			
Plunger Cap		X			
Cam			X		
Follower			X		
Cam Shaft Seal			X		
Cam Shaft			X		
Crank			X		
Connecting Crank Arm			X		
Disk Crank Arm			X		
Lock Plunger			X		
Load Ring Segment			X		
Bearing			X		
Spring			X		
Spring Pin			X		
Latch Cam			X		
Control Drum Drive Pin			X		
Spring Pin			X		
Cam Actuator Disk			X		
Connecting Rod			X		
Connecting Arm			X		
Corrugated Band				X	
Flat Band				X	
Band Pin				X	
Plunger Guide					X

TABLE 2-2
DEVELOPMENT TESTS USED IN SUPPORT OF TRADE STUDY NO. 778

<u>Development Test Identification</u>	<u>Supporting DRM or Trade Study Section Using Test Results</u>
63DE-205, Graphite Foil Set Test	Structural & Reactor Design
63DE-214, Plunger Pin Friction Test	Structural & Reactor Design
TS-209, Low Frequency Vibration Test of Partial Length Core	Structural & Reactor Design
TS-119, Resistance to Erosion of Pyrofoil	Reactor Design
DM-022.1, Friction Coefficients of Graphites	Test in Progress

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

~~ATOMIC ENERGY ACT OF 1954~~

Astronuclear
Laboratory

2.1 DESIGN APPROACH 1 (REFERENCE DESIGN)

2.1.1 General Description of Design Approach 1

(CRD) The lateral support system, shown in Figure 2-1, is the reference design which resulted from the NSS Radial Dimension Optimization Study, WANL-TME-2707. The lateral support system, which is supported by the reflector support structure, consists of 21 rows of inner and outer seal rings, insulation, 21 rows of plunger mechanisms and associated hardware.

(CRD) The inner seal ring, which is a combination seal and load ring, consists of nine segments that transmit bundling pressure from the plungers to the core. The segments, which have an overlap joint, allow the seal ring to expand and contract with the core while maintaining a sufficient amount of bundling pressure. The segments are mated in such a manner that the inner ring interfaces with the outer ring at 30 degrees and with the plungers at 60 degrees as shown in Figure 2-1A.

(CRD) The outer seal ring, which also consists of nine segments with overlapping ends, is supported by a ledge projecting from the inner wall of the reflector structure. The segments are designed in such a manner that the inner segment holds the outer segment in place against the ledge once the core and plungers are installed. The retainers, shown in Figure 2-1A, hold the outer segments in place during assembly.

(CRD) The insulation, see Figure 2-1A, is designed to protect the reflector from the high core temperatures. It can be seen that the insulation, which is a graphite foil lamination, is positioned between the ledges of the reflector support structure and retained in place by the outer seal segments.

(CRD) The plunger mechanism consists of the capsule, cap, spring, plunger, sleeve, capsule seal and cap seal. The capsule in this concept serves a number of functions. It is used to

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

~~ATOMIC ENERGY ACT OF 1954~~

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

~~Atomic Energy Act of 1954~~

Figure 2-1. List of Materials (939J733)

QTY	ITEM NO.	DESCRIPTION	CODE IDENT NO.	PART OR IDENTIFYING NO.	MATERIAL	SPECIFICATION	NOTE
	7	LOCKING DEVICE			CRES	QQ S 763 304 CONDA	
	70	BOLT .375 24 UNF 2A			CRES	AMS 5737 (A2B6)	
	69	SCREW .250 28 UNF 2A			CRES	AMS 5737 (A2B6)	
	68	LOCKING DEVICE			CRES	QQ S 763 304 CONDA	
1512	67	SCREW .250 28 UNF 2A			CRES	AMS 5737 (A2B6)	
189	66	RETAINER SEGMENT			CRES	AMS 5737 (A2B6)	
18	65	LOCKWASHER	945C493H01-		CRES	QQ S 766 304 CONDA	
18	64	NUT, RETAINER	945C492H01-		AL	QQ A 225/B (6061 T6)	
72	63	LOCKING DEVICE	946C902H01		CRES	QQ S 763 304 CONDA	
72	62	BOLT .375 24 UNF 2A			CRES	AMS 5737 (A2B6)	
108	61	PIN, CONTROL PLATE	944B 77H01A		AL	QQ A 225/B (6061 T6)	
1503	60	RIVET CONTROL PLATE			CU	PD 13406 AC	
36	59	LOCKING DEVICE			CRES	QQ S 763 304 CONDA	
108	58	KEENSERT .375 24 UNF 3A	KNL		CRES	AMS 5737 (A2B6)	
36	57	LOCKING DEVICE			CRES	QQ S 763 304 CONDA	
36	56	BOLT .375 24 UNF-2A			CRES	AMS 5737 (A2B6)	
36	55	LOCKING DEVICE	947C061H01		CRES	QQ S 763 304 CONDA	
36	54	BOLT .625-18 UNF 3A	97BD965H01-		CRES	AMS 5735 (A2B6)	
72	53	LOCKING DEVICE	944C461H01-		CRES	QQ S 763 304 CONDA	
72	52	BOLT .250 28 UNF 2A			CRES	AMS 5737 (A2B6)	
18	51	LOCKWASHER	944C554H01-		CRES	QQ S 766 304 CONDA	
18	50	NUT FORWARD BRG RETAINER			AL	QQ A 225/B T6 (6061)	
18	49	LOCKWASHER, BRG NUT	945C494H01-		CRES	QQ S 766 304 CONDA	
18	48	NUT, AFT BRG RETAINER	945C495H01-		AL	QQ A 225/B (6061 T6)	
36	47	BOLT .375-24 UNF-2A			CRES	AMS 5737- (A2B6)	
18	46	FILLER, SEGMENT			AL	QQ-A-250/11 T4 (6061)	
18	45	HOUSING, SPRING			AL	QQ-A-225/B T6 (6061)	
18	44	SPRING, DRIVE SHAFT			CRES	AMS 5737 (A2B6)	
18	43	RETAINER INSULATION			AL	QQ-A 250/11 T4 (6061)	
18	42	INSULATOR, DRUM CYLINDER			GRAFOIL	PDS 30097-1	
1	41	SEAL, FORWARD IMPEDANCE			CRES	AMS-5525 (A2B6)	
756	40	O RING .062 DIA X .012 WALL 1500 OD			AL	WW T-700/6 T6 (6061)	
756	39	O RING .062 DIA X .012 WALL 875 OD			AL	WW-T-700 /6-T6 (6061)	
1	38	O RING .125 DIA X .012 WALL 42550 OD			CRES	AISI 321 Ag PLATED	
1	37	SEAL, AFT STRUCTURE INNER			CRES	AMS 5525 (A2B6)	
1	36	SEAL, AFT STRUCTURE OUTER			CRES	AMS 5525 (A2B6)	
18	35	NUT, ADJUSTMENT			CRES	AMS 5737 (A2B6)	
756	34	PIN, LOCATING			AL	QQ-A 225/B T6 (6061)	
1	33	SCREEN			CRES	QQ W 423 CL304 CONDA	
189	32	SEGMENT, INSULATION			GRAFOIL	PDS 30097-1	
189	31	SEGMENT, INNER SEAL			GRAPHITE	PDS 30019-1 (ZTA)	
189	30	SEGMENT, OUTER SEAL			GRAPHITE	PDS 30019-1 (ZTA)	
756	29	SPRING, LATERAL SUPPORT			CRES	AMS 5737 (A2B6)	
756	28	PLUNGER			GRAPHITE	PDS 30086-1 (P03)	
756	27	SPRING, SEGMENT RETAINER			CRES	AMS 5525 (A2B6)	
756	26	SLEEVE			CRES	AMS 5737 (A2B6)	
756	25	CAP, CAPSULE			AL	QQ-A-250/11 T6 (6061)	
756	24	CAPSULE			AL	QQ A 225/B-T6 (6061)	
1	23	RING, CLAMP			AL	QQ-A-250/11-T6 (6061)	
18	22	PAD, STANDOFF			AL	QQ-A 250/11 T6 (6061)	
18	21	STANDOFF			CRES	AMS 5737 (A2B6)	
36	20	BEARING	945C732H01		CRES	440 C	
18	19	COUPLING			CRES	QQ-S-763 304 CONDA	
18	18	SPRING, ANTI-BACKLASH			CRES	AMS-5525 (A2B6)	
18	17	STOP			CRES	QQ-S-763 304 CONDA	
54	16	VANE, CONTROL			CU B ¹⁰	PDS 30127-1	
18	15	SUPPORT, AFT BEARING			AL	QQ A 225/B-T6 (6061)	
18	14	HOUSING, FORWARD BRG			AL	QQ A 225/B T6 (6061)	
18	13	SPRING, DRUM CYLINDER			CRES	AMS-5737 (A2B6)	
18	12	SHAFT, AFT DRUM			AL	QQ A 225/B T6 (6061)	
18	11	SHAFT, FORWARD DRUM			AL	QQ A 225/B T6 (6061)	
18	10	CAN, DRUM			AL	WW T-700/6 T6 (6061)	
18	9	CYLINDER, DRUM			Be	PDS 30018-1	
18	8	LINER, DRUM BORE			AL	WW-T-700/6 T6 (6061)	
1	7	CYLINDER, LOCATING			AL	QQ A 367 6061 T652	
1	6	CAN, REFLECTOR BAFFLE			AL	QQ A-250/11 T6 (6061)	
378	5	SEGMENT, OUTER REFLECTOR			Be	PDS 30018-1	
378	4	SEGMENT, INNER REFLECTOR			Be	PDS 30018-1	
1	3	RING, AFT SUPPORT			AL	QQ-A-250/11 T6 (6061)	
1	2	RING, FORWARD EXTENSION			AL	PDS 30258-1 (6061-T6)	
1	1	CYLINDER, STRUCTURAL			AL	PDS 30258-1 (6061-T6)	

LIST OF MATERIALS

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

~~Atomic Energy Act of 1954~~

Figure 2-1. Reflector, Aluminum Structure (939J733)

PAGE BLANK

2-11

Figure 2-1A. Design Approach 1 (Reference Design)(613419-24B)

fasten the beryllium segments to the support structure. It provides a housing for the spring and plunger while maintaining a gas tight barrier between the outside of the capsule and the core. In addition to the above, the capsule transmits the spring load back to the support structure.

(CRD) As can be seen, the cap provides a closure for the end of the capsule which facilitates the installation of the plunger and spring. It also provides a bearing surface for the outer end of the spring.

(U) The spring, which bears on the cap on one end and the plunger at the other, provides the bundling force which is transmitted through the plunger to the inner seal segment. It is a metallic rectangular wire compression spring designed to supply bundling pressure to the core during all phases of operation.

(U) The plunger, as shown, is a graphite cylinder with an enlarged shoulder on one end and the other end machined at an angle. The end with the shoulder mates with the spring while the angled end is designed to bear against the inner seal segment. A hole is machined through the center of the plunger to assure that gas can not be trapped in the capsule that might affect the normal operation of the plunger.

(CRD) The sleeve is a hollow cylindrical fastener with external threads on one end and a shoulder on the other. The sleeve is designed so that it can be wrenched at the shoulder end and crimped (for locking purposes) at the threaded end. The sleeve serves two functions: (1) it is used to fasten the capsule to the reflector support structure, (2) it provides a bearing surface which guides the plunger.

(CRD) The cap seal and the capsule seal are metallic O-ring seals which are used to prevent the high pressure coolant in the reflector from entering the capsule. By sealing the capsule in this manner, the pressure inside the capsule is essentially at the same pressure as that of the core periphery. This eliminates the need for any seals between the sleeve and reflector structure and between the sleeve and plunger.

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~
~~ATOMIC ENERGY ACT OF 1954~~

2.2 DESIGN APPROACH 2 (PARALLEL ANGLE SEAL)

2.2.1 General Description of Design Approach 2

(CRD) This design approach, shown in Figure 2-2, evolved from the reference design just described. It includes features which are designed to reduce the possibility of component failure due to binding and bending after exposure to a hard vacuum environment. This system, like the reference design, is supported by the reflector support structure. It consists of 21 rows of inner and outer seal rings, insulation, 21 rows of plunger mechanisms and other necessary hardware.

(CRD) The inner and outer seal rings are segmented to allow for expansion and contraction. The inner segments which bear against the core periphery are seated against the outer segments which transmit force to the reflector support structure. The outer segments are positioned by a ledge projecting from the support structure and are held in place by retainers as shown in Figure 2-2A. The mating surfaces of the inner and outer seal segments are parallel to ensure positive motion during core expansion and contraction. The small seal angle reduces the possibility of binding due to the fact that the smaller the seal angle the smaller the axial force component which forces the inner seal against the outer.

(CRD) The plunger mechanism in this design approach is similar to that of the reference design. The major difference is that an unguided plunger is used instead of the guided plunger. To accommodate this, a plunger sleeve has been added to the mechanism and the capsule sleeve was enlarged.

(CRD) The plunger, as shown in Figure 2-2A, bears against the inner seal segment on one end and against the plunger sleeve on the other end. The plunger is attached to the plunger sleeve by the spherical ball end as shown. This captures the plunger yet it does not restrict the plunger motion that is necessary for normal lateral support operation. The plunger sleeve, which is guided by the capsule sleeve, is coated with a solid lubricant to prevent seizure due to welding when operating in a hard vacuum environment. The unguided plunger provides for an incredible single point failure potential since the plunger bending stress is eliminated.

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~
~~ATOMIC ENERGY ACT OF 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act~~

Figure 2-2. List of Materials (940J438)

1		18	STRUCTURE			AL	PDS 30259	
189		17	SPRING, SEGMENT RETAINING			CRES	AMS 5525 (A286)	
378		16	INSERT, THREADED		MS 21209-FI-15	STL		
378		15	RETAINER, OUTER SEAL			CRES	AMS 5737 (A286)	
1512		14	BOLT, CAP			CRES	QQ 5-7636 CLASS 303	
756		13	SEAL, O-RING 1.500 O.D			AL	WW-T-70016 (6061)	
756		12	SEAL, O RING 1.188 O.D			AL	WW-T-70016 (6061)	
756		11	SPRING, PLUNGER			CRES	AMS 5737 (A286)	
756		10	CAP SPRING			AL	QQ-A 225/8 (6061-T6)	
756		9	CAP, PIN			CRES	AMS 5737 (A286)	
756		8	PIN, PLUNGER			GRAPHITE	PDS 30086-1	
756		7	SLEEVE, PLUNGER					
756		6	SLEEVE, CAPSULE			CRES	AMS 5737 (A286)	
756		5	CAPSULE, SPRING			AL	QQ-A 225/8 (6061-T6)	
189		4	SEGMENT, INSULATING			GRAFOIL	PDS 30097-1	
189		3	SEGMENT, INNER SEAL			GRAPHITE	PDS 30019-1	
189		2	SEGMENT, OUTER SEAL			GRAPHITE	PDS 30019-1	
9		1	SEGMENT, OUTER SEAL - FWD			GRAPHITE	PDS 30019-1	
	SYM	ITEM NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT NO.	PART OR IDENTIFYING NO.	MATERIAL	SPECIFICATION	ZONE
QTY. REQD	LIST OF MATERIALS							

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act~~

Figure 2-2. Parallel Angled Seals,
 Lateral Support (940J438)

Figure 2-2A. Design Approach 2 (Parallel Angle Seal) (613419-25B)

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~
~~ATOMIC ENERGY ACT OF 1954~~

2.3 DESIGN APPROACH 3 (LOCKED CORE WITH CONTROL DRUM RELEASE MECHANISM)

2.3.1 General Description of Design Approach 3

(CRD) The control drum actuated core lock mechanism was created to provide the Nuclear Subsystem (NSS) with a two-phase lateral support system. The two-phase system is desirable since the G load requirements for the ground handling and launch phases of operation are greater than the requirements for engine operation in space. Another contributing factor to the desirability of a two-phase system is the increase in coefficient of friction of graphite when subjected to the hard vacuum environment found in space.

(CRD) It has been determined that by increasing the plunger length in a guided plunger type lateral support system, the possibility of plunger lockup due to friction is reduced. Based on this, an increase in plunger length would allow the lateral support system to operate satisfactorily with an increase in graphite friction. The increase in plunger length, however, reduces the space available in the capsule for the compression spring. This reduction in spring size, reduces the available spring load which in turn reduces the G load capability of the lateral support system. Since the G load requirement is less for engine operation in space and it is known that graphite friction increases in a space environment, the springs can be sized for space application if some other method was incorporated into the system to satisfy the higher G load requirements of ground handling and launch. It has been determined that this higher G load capability could be obtained by restraining lateral translation of the aft end of the core within the reflector with a core lock mechanism.

(CRD) The lock mechanism in this design approach, which is actuated by the control drums, is designed to operate in the following manner:

- 1) Core will be locked at assembly for ground handling and launch.
- 2) Each control drum is free to rotate from five to 100 degrees for control drum checkout with the core locked.
- 3) Core is unlocked by rotating nine control drums, one at a time out to 170 degrees.

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~
~~ATOMIC ENERGY ACT OF 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act, 1954~~

Figure 2-3. List of Materials (939J724)

18	23	PIN, LATCH CAM			CRES	AMS 5737 (A286)		
9	22	SEGMENT, OUTER SEAL			GRAPHITE	PDS 30019-1		
9	21	SEGMENT, LOAD RING			GRAPHITE	PDS 30019-1		
9	20	SEGMENT, LOAD RING SUPPORT			GRAPHITE	PDS 30019-1		
18	19	O-RING-.062DIA X .012WALL-.500 OD			AL	WW-T-700/6-T6 (6061)		
18	18	O-RING-.062DIA X .012WALL-1.687 OD			AL	WW-T-700/6-T6 (6061)		
18	17	O-RING-.062DIA X .012WALL-.875 OD			AL	WW-T-700/6-T6 (6061)		
18	16	PLUNGER			GRAPHITE	PDS 30086-1		
18	15	SLEEVE			CRES	AMS 5737 (A286)		
18	14	CAP, CAPSULE			AL	QQ-A-250/11-T6 (6061)		
18	13	CAPSULE			AL	QQ-A-225/8-T6 (6061)		
18	12	FOLLOWER, CAM			CRES	AMS 5737 (A286)		
18	11	SPRING, LATERAL SUPPORT			CRES	AMS 5737 (A286)		
9	10	ARM, CONNECTING			CRES	AMS 5737 (A286)		
18	9	ROD, CONNECTING			CRES	AMS 5737 (A286)		
18	8	SPRING			CRES	AMS 5737 (A286)		
18	7	PIN, SPRING			CRES	AMS 5737 (A286)		
18	6	BEARING						
18	5	CAM, LATCH			CRES	AMS 5737 (A286)		
36	4	CRANK			CRES	AMS 5737 (A286)		
18	3	SHAFT, CAM			CRES	AMS 5737 (A286)		
18	2	CAM			CRES	AMS 5737 (A286)		
18	1	DISK, CAM ACTUATOR			CRES	AMS 5737 (A286)		
	SYM	ITEM NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT NO	PART OR IDENTIFYING NO	MATERIAL	SPECIFICATION	ZONE
QTY REQD								
PARTS LIST								

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act, 1954~~

Figure 2-3. Locked Core With Control Drum
Release Mechanism (939J724)

Figure 2-3A. Design Approach 3
(Locked Core With Control Drum Release Mechanism) (613A19-26B)

(CRD) 4) Each control drum is free to rotate from five to 170 degrees with core unlocked.

5) Each lock mechanism is a duplex system which can be actuated by rotating any one of two control drums.

6) Core is relocked by rotating nine control drums, one at a time out to 175 degrees and then back to 100 degrees.

(U) The core lock mechanism could actually be used in conjunction with any of the lateral support design approaches presented in this trade study. In this description, however, it is being used in conjunction with a lateral support system similar to the reference design.

(CRD) The lateral support system, see Figure 2-3, which is used in conjunction with the core lock mechanism, has 20 forward rows of seal rings and plunger mechanisms like the reference design except that the plunger length is increased and the compression spring length is decreased. The aft row of seal rings in this system is replaced with a load ring, the core lock mechanism, and 18 regular plunger mechanisms.

(CRD) The load ring is a segmented ring with a rectangular cross-section, as shown in Figure 2-3A. It is guided, axially, by the two stationary outer rings and forced against the core by the regular plungers and the core lock plungers.

(CRD) The core lock mechanism actually consists of nine individual mechanisms. The nine mechanisms are designed to operate individually in conjunction with their respective control drums. Each mechanism is attached to two specific control drums and can be actuated by either one. The individual mechanisms consist of two cam actuator assemblies, two special plunger assemblies, two connecting rods, a connecting arm, and other assembly hardware.

(CRD) A cam actuator assembly is made up of: cam actuator disk, bearing and latch device. The disk is fastened to the control drum shaft by the bearing as shown in Figure 2-3B. The disk is slotted so that the control drum, which is equipped with a disk drive pin, is free to rotate a specific amount without engaging the disk. The cam actuator disk also houses the latch device which is actuated only when the core is relocked.

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
Atomic Energy Act, 1954

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
Atomic Energy Act, 1954

Figure 2-3B. Design Approach 3
(Locked Core With Control Drum Release Mechanism) (613A19-27B)

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~
~~ATOMIC ENERGY ACT OF 1954~~

- (CRD) The latch device consists of a spring loaded pin and a latch cam which is used to position the pin. The pin, which is spring loaded against the cam, is designed so that it can be inserted into the slot of the disk by rotating the latch cam. The pin is inserted by simply rotating the cam actuator disk past a projection which is located in the bearing housing. The projection causes the latch cam to rotate which in turn inserts the pin.
- (CRD) The latch cam is a three lobe cam which has two lobes located 180 degrees from each other in the same plane and the other located 90 degrees from the two lobes in another plane. The lobes on the cam are placed in two planes, as shown in Figure 2-3B, so that the lobe in one plane can be used to insert the pin and the lobe in the other plane is used to retract the pin. The pin insertion is accomplished by rotating the control drum clockwise, whereas the retraction requires the control drum to be rotated counterclockwise.
- (CRD) There are two types of plunger assemblies in the aft row. Eighteen of the assemblies are like the ones found in the other 20 rows except that the plungers are made to be compatible with the rectangular load rings. The other 18 plunger assemblies are used in conjunction with the core lock mechanism.
- (CRD) The special plunger assembly consists of a capsule, sleeve, cap, plunger, spring, follower, cam, cam shaft, crank, three seals, and other assembly hardware.
- (CRD) As shown in Figure 2-3A, the capsule, sleeve, and cap serve the same function as in the reference design. In this design approach, however, the capsule also houses the cam and provides for an access hole for the cam shaft.
- (CRD) The plunger in this approach is designed for two-phase operation. When the core is locked for ground handling and launch, the plunger is used to transmit radial loads from the load ring directly to the cam which in turn transmits the loads through the capsule and sleeve to the reflector support structure. When the core is unlocked for engine operation, the core loads are transmitted through the plunger and spring to the cam. In the unlocked condition, the plunger assembly is free to operate like the other plunger assemblies in the lateral support system. The crank, which is fastened to the cam shaft, has two arms. One

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~
~~ATOMIC ENERGY ACT OF 1954~~

Figure 2-3C. Design Approach 3
(Locked Core With Control Drum Release Mechanism) (613419-28B)

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

~~ATOMIC ENERGY ACT OF 1954~~

Astronuclear
Laboratory

arm is used to transmit the actuator disk rotation to the cam shaft and the other is used to impart the rotation of one cam shaft on another.

(CRD) Two different linkages are used to hook the core lock mechanism together. A connecting rod is used to attach the crank to the actuator disk which is found on each control drum. The connecting arm provides a means for hooking the crank of one plunger assembly to the crank of another. This hooking together of the connecting cranks allow two cams to be actuated by rotating any one of the two control drums.

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

~~ATOMIC ENERGY ACT OF 1954~~

PAGE BLANK

2.4 DESIGN APPROACH 4 (KEYED SEAL WITH METAL BAND)

2.4.1 General Description of Design Approach 4

(CRD) The keyed seal with metal band design approach, shown in Figure 2-4, was introduced in an effort to eliminate possible binding problems and increase the lateral load capability of the lateral support system. This is also an effort to eliminate the plunger mechanisms which in turn eliminate the large cavities in the beryllium.

The basic idea of the keyed seal with metal band design approach is shown in Figure 2-4A.

Figure 2-4A

(CRD) The object is to bundle the core in such a manner that it behaves like a single right circular cylinder with keys protruding from it. The keys interlock with the reflector and restrain lateral translation of the core within the reflector. It can be seen in Figure 2-4A that although the keys keep the core centered with respect to the reflector, they do allow the core to expand and contract.

(CRD) The lateral support system in this design approach consists of 21 rows of inner and outer seal rings equipped with metal bands and retainer hardware as shown in Figure 2-4B.

(CRD) The seal rings, which act as seal and load rings, are segmented with overlapping ends to allow for expansion and contraction. The inner and outer segments both have a rectangular cross-section and are keyed to each other as shown. The outer segments are

Figure 2-4. List of Materials (939J737)

378	17	LOCKING DEVICE			CRES	AMS 5737 (A-286)		
378	16	NUT, RETAINER			CRES	AMS 5737 (A-286)		
12	15	PIN			CRES	AMS 5737 (A-286)		
1	14	LINER, INSULATION			TUNGSTEN	AMS 7858		
9	13	SEGMENT, AFT OUTER SEAL			GRAPHITE	PDS 30019-1 (ZTA)		
9	12	SEGMENT, RETAINER			GRAPHITE	PDS 30019-1 (ZTA)		
189	11	NUT, RETAINER			CRES	AMS 5737 (A-286)		
378	10	RETAINER, REFLECTOR SEG.			CRES	AMS 5737 (A-286)		
189	9	RETAINER, OUTER SEAL SEG			CRES	AMS 5737 (A-286)		
189	8	INSULATOR			PYROGRAPH	PDS 30015		
189	7	SEGMENT, INSULATION			GRAFOIL	PDS 30097-1		
9	6	BAND, CORRUGATED			CRES	AMS 5737 (A-286)		
12	5	BAND, FLAT			CRES	AMS 5737 (A-286)		
81	4	SEGMENT, INNER SEAL			GRAPHITE	PDS 30019-1 (ZTA)		
108	3	SEGMENT, INNER SEAL			GRAPHITE	PDS 30019-1 (ZTA)		
171	2	SEGMENT, OUTER SEAL			GRAPHITE	PDS 30019-1 (ZTA)		
1	1	STRUCTURE			AL	PDS 30258 (6061)		
QTY REQD	SYM	ITEM NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT NO	PART OR IDENTIFYING NO	MATERIAL	SPECIFICATION	ZONE
LIST OF MATERIALS

Figure 2-4. Keyed Seal With Metal Band,
Lateral Support (939J737)

PAGE BLANK

Figure 2-4B. Design Approach 4 (Keyed Seal With Metal Band) (613419-23B)

~~CONFIDENTIAL~~
RESTRICTED DATA
ATC 11-11-1954

positioned by the ledged protruding from the reflector support structure and are held in position by the retaining screws which pass through the reflector structure. As can be seen, the inner segments are guided by the outer segments and bear against the core. Pyro-graphite insulation is provided between the inner segments and the core to aid in cooling the segments and protects the metal bands from the high core temperatures.

(CRD) The metal bands which encircle the inner segments provide the mechanical bundling and maintain the core as a unitized cylinder. The forward 12 rows of seals are bundled by a flat band whereas corrugated bands are used on the aft nine rows. The flat bands are considered adequate on the forward end due to the low core thermal expansion. The corrugated bands are used on the aft end to allow for a considerable amount of core expansion while maintaining the desired mechanical bundling pressure.

~~CONFIDENTIAL~~
RESTRICTED DATA
ATC 11-11-1954

~~CONFIDENTIAL~~

~~ATQ 1954~~

2.5 DESIGN APPROACH 5 (WEDGED SEAL WITH END GUIDED PLUNGERS)

2.5.1 General Description of Design Approach 5

(CRD) This design approach was conceived to eliminate some of the potential problems associated with operating the lateral support system in a hard vacuum of 10^{-9} torr. Since the coefficient of friction of graphite increases in a hard vacuum, emphasis was placed on minimizing the condition that could cause lockup of graphite components. This approach, see Figure 2-5, in some respects is the same as the reference design. It is supported by the reflector support structure and consists of 21 rows of inner and outer seal rings, insulation, assembly hardware, and 21 rows of plunger mechanisms. The major difference in this approach is that plunger guides have been added to facilitate loading the plungers primarily in compression.

(CRD) The inner and outer seal rings are segmented into nine equal segments. A scarf joint technique is used to provide a continuous seal at the segment joints while allowing the rings to circumferentially expand or contract. The outer segments, as shown in Figure 2-5A, are positioned in a groove against the reflector support structure and held in place by the segment retainers. The outer segments have a key-way which facilitates the keying of the inner segment to the outer. The inner segments, which bear against the core and the outer segments, transmit the spring force from the plungers to the core. A key-way is also provided in the inner segments that maintain the segment in position relative to the outer segment.

(CRD) The plunger mechanism, see Figure 2-5A, is the same as that used in the reference design except for the sleeve, spring, and plunger. Since the plunger is maintained in position at the core end by the plunger guide and the reflector end by the capsule, the sleeve is only used to fasten the capsule to the reflector support structure. The sleeve diameter is increased a small amount so that it does not interfere with plunger motion. The spring can be made longer in this design approach since the flat seal segments require less total

~~CONFIDENTIAL~~
~~ATQ 1954~~
ENERGY

Figure 2-5. List of Materials (929F266)

756	16	SEAL, CAPSULE SLEEVE, O RING	AL	WW-T-700/6 (6061)
596	15	RETAINER, OUTER SEAL	CRES	AMS5737 (A286)
1512	14	BOLT CAP	CRES	QQ S-7636 CL 303
756	13	SEAL, CAP, O RING	AL	WW-T-700/6 (6061)
756	12	SEAL, CAPSULE, O RING	AL	WW-T-700/6 (6061)
756	11	SPRING, PLUNGER	CRES	AMS5737 (A286)
756	10	CAP, SPRING	AL	QQ A-225/8-T6 (6061)
756	9	SPRING SEGMENT RETAINING	CRES	AMS5525 (A286)
756	8	PIN, PLUNGER	GRAPHITE	PDS30086-1 (P-03)
378	7	GUIDE, PLUNGER	GRAPHITE	PDS30086-1 (P-03)
756	6	SLFEEV, CAPSULE	CRES	AMS5737 (A286)
756	5	CAPSULE, SPRING	AL	QQ-A-225/8-T6 (6061)
189	4	SEGMENT, INSULAT ON	GRAFOIL	PDS30097-1
189	3	SEGMENT, INNER SEAL	GRAPHITE	PDS30019-1 (ZTA)
198	2	SEGMENT, OUTER SEAL	GRAPHITE	PDS30019 1 (ZTA)
1	1	STRUCTURE	AL	PDS30259

Figure 2-5. Wedged Seal With End-Guided Plungers, Lateral Support (929F266)

PAGE BLANK

Figure 2-5A. Design Approach 5
(Wedged Seal With End Guided Plungers) (613419-44C)

plunger travel. The plunger end and shoulder are both spherical to accommodate free rotation and translation during operation. The spherical end of the plunger is also used to supply a separating force between the inner seal segment and the plunger guide.

(CRD) The plunger guide is essentially a wedge block which serves several functions. As can be seen in Figure 2-5A, it is a short block that is forced against the outer seal segment and the core by a plunger. The angle on the plunger guide causes the plunger to be forced against the inner seal segment which bears against the core and outer seal segment. The guide, therefore, is used to guide the end of the plunger, transmit the plunger load to the core, and provide for positive contact between the inner and outer seal segment. Since the guide is keyed to the inner and outer seal segment, it also serves as a segment locating device.

3.0 COMPARISON MATRIX

This section describes the method of constructing the Comparison Matrix and the use of the matrix in evaluating design approaches and selecting a lateral support design approach.

The matrix is constructed to provide a means of evaluating each design approach described in Section 2.0 against the requirements defined in Section 1.0. Each requirement is entered in the matrix as a row heading and each design approach is entered as a column heading. All the requirements of Section 1.0 are divided among five consideration groups. The functional and technical requirements of Section 1.0 are contained in the three consideration groups: Reliability and Safety, Performance and Weight. The non-technical requirements are entered in two consideration groups: Development and Qualification and Schedule. The comparison matrixes containing these consideration groups are shown in Tables 3-1 through 3-9.

The entries in the matrixes are data and/or descriptions abstracted from appropriate analysis DRMs referenced at end of Section 4.0. The entries define the results of analysis of each design approach ability relative to a consideration.

The design approaches are evaluated against each requirement by assigning each approach an "emphasis factor: which defines the approaches standing among all the concepts for the given requirement.

The emphasis factor assignment is made under the following rule:

<u>Emphasis Factor Criteria</u>		
<u>Selection</u>	<u>Value</u>	<u>Rule</u>
First Selection, a	0 to 1.0	
Second Selection, b	0 to 1.0	$b < a$
$\vdots$	$\vdots$	$\vdots$
Nth Selection, n	0 to 1.0	$n < n-1$
$\sum_{1}^N$		1.0

The emphasis factors are shown in the matrix as circled numbers.

The evaluation of each design approach's standing for each consideration group is done through average emphasis factors. Average emphasis factors are shown at the bottom of each consideration group. Average emphasis factors for each consideration group are multiplied by a specific weighting factor and this value is entered into the summary matrix shown in Table 3-9 . The sum of these weighted average emphasis factors shown at the bottom of Table 3-9 for each design concept defines the overall Figure of Merit, i.e., the relative standing of each design approach relative to all considerations. The highest value represents the best design approach relative to the consideration groups or the requirements. The following weighting factors were used:

<u>Consideration</u>	<u>Weighting Factor</u>
Reliability and Safety	.30
Performance	.25
Weight	.25
Development and Qualification	.10
Schedule	.10

CONFIDENTIAL
~~RESTRICTED DATA~~
 1954

3-3

CONFIDENTIAL
~~RESTRICTED DATA~~
 1954

NOMENCLATURE		ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
RELIABILITY OBJECTIVE Achieve the Reliability of 999839	Overall Reliability Estimate	(.067) Very Low	(.333) 9,892 ($Q = 1.08 \times 10^{-5}$)	(.007) Very Low	(.067) Very Low	(.406) 9,886 ($Q = 1.14 \times 10^{-7}$)	
	Principal Failure Modes Affecting Reliability	Interference with core expansion due to high friction, in a hard vacuum, of the plunger pin O.D. causing the pin to bind and break and interfere with movement of the inner seal segment. This is based on not developing a technique for friction control.	Interference with core expansion due to breaking of the outer seal segment caused by thermal stresses. It is assumed the breaking results in fragments which can lodge in the space required for inner seal segment movement.	Same as Design Approach 1	Loss of sealing capability and of mechanical bundling force due to yielding of the metal bands.	Same as Design Approach 2 except voids are available in the lateral support system which accommodate broken pieces better than the other design approaches.	
	SAFETY OBJECTIVE: Minimize Possibility of Loss of Emergency Mode Capability						
	Most Probable Category IV Failures	(.140)	(.200)	(.090)	(.300)	(.270)	
	Interference with Core Expansion	High (relative) probability of pins and seal segments breaking. Low coefficient of friction allowed before lockup occurs.	Low (relative) probability of pins breaking and intermediate (relative) probability of seal segments breaking. Intermediate (relative) coefficient of friction allowed before lockup occurs.	Same as Design Approach 1 except core lock mechanism can fail and lock LSS during power operation.	Low (relative) probability metal band and seal segments breaking. Band can retain broken inner seal segments. High (relative) coefficient of friction allowed before lockup occurs.	Low (relative) probability of pins and seal segments breaking. High (relative) coefficient of friction allowed before lockup occurs.	
	Category IIIB Failures	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	
	RELIABILITY & SAFETY AVERAGE* EMPHASIS FACTOR	.091	.289	.075	.144	.401 ▲	
			*Relative Weighting	.67 Reliability,	.33 Safety		

NOMENCLATURE TABLE 3-2 PERFORMANCE CONSIDERATIONS REFLECTOR ASSEMBLY EC-677559		<div style="text-align: center;"> ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES </div>					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
(Lateral Support Function)	Prevent Core Components From Separating	(250) High Mechanical Bundling Due to Angled Seal Segments	(190) Reduced Mechanical Bundling Due to Reduced Seal Angle, Increased Uncertainties in Pneumatic Bundling	(250) Same as Design Approach 1	(100) Low Mechanical Bundling and Large Uncertainties in Pneumatic Bundling	(210) Same as Design Approach 2 Except Less Uncertainties Associated With Pneumatic Bundling	
	Prevent Core From Impacting Reflector for Lateral Loads up to 3 g at Frequencies > 6 Hz Prior to and Through Launch Boost Phase	(220) Proven Dynamic Concept	(190) Keyed Seal Approach Requires Increased Bundling and/or Design Modifications	(300) Same as Design Approach 1 Except Core Lock Provides Redundant System	(100) Same as Design Approach 2 Except Limited Capability for Bundling	(190) Same as Design Approach 2	
	Prevent Core From Impacting Reflector for Lateral Loads up to 1.5 g at 6 - 500 Hz Subsequent to Boost Phase	(230) Proven Dynamic Approach With Increased Capability for Lower g Environment	(230) Keyed Seal Approach Appears More Feasible for Lower g Levels	(230) Same as Design Approach 1	(080) Capability Limited Due to Metal Bands	(230) Same as Design Approach 2	
	Thermal Stresses in Graphite Seal Segments	(200) Reference Design	(200) Similar to Design Approach 1	(200) Same as Design Approach 1	(100) Presence of Metal Bands Leads to Increased Thermal Stress	(300) Least Amount of Graphite in SS, Hence Less Heat Generation Resulting in Lower Thermal Stresses	
	Provide Capability for Core Radial Thermal Expansion of 1.8 Percent from the As-Assembled Dimensions	(200) Meets Requirements	(200) Same as Design Approach 1	(200) Same as Design Approach 1	(200) Same as Design Approach 1	(200) Same as Design Approach 1	
	Maintain Structural Integrity in a Coast Environment (Vacuum Effects)	(100) Limited Plunger Friction Capability	(250) Good for Coefficient of Friction Approaching 0.7 on Graphite Components	(130) Same as Design Approach 1	(250) Suitable for Small (.050 to .10) Deflections for Coefficient of Friction Approaching 1.0	(300) Good for Large Coefficient of Friction Approaching 1.0	
	Provide Lateral Support Capability After Space Soak	(150) Limited Plunger and Seal Friction Capability	(250) Good for Coefficient of Friction Approaching 0.7 on Graphite Components	(130) Same as Design Approach 1	(100) Does Not Provide Lateral Support Capability	(250) Good for Large Coefficient of Friction Approaching 1.0	

NOMENCLATURE TABLE 3.3 PERFORMANCE CONSIDERATIONS REFLECTOR ASSEMBLY EC-677559		ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
Core Bundling Function)		(210) Seal Seating Initiated by Plunger Load (Reduced Effect), Core Radial Expansion, and Aftward Axial Displacement of Filler Strips (240) Seal Wedge Angle Increases Spring Bundling	(200) Seal Seating Initiated by Plunger Load (Reduced Effect) Core Radial Expansion (Reduced Effect) and Aftward Axial Displacement of Filler Strips (210) Similar to Design Approach 1 But Seal Wedge Angle Decreased	(210) Same as Design Approach 1 (250) Same as Design Approach 1	(080) Seal Seating Initiated by Aftward Axial Displacement of Filler Strips (100) Limited by Metal Band Temperature Effects	(300) Seal Seating Initiated by Plunger Load Wedging Action and Aftward Axial Displacement of Filler Strips. Pressure Distribution Also Depends on Bleed Flow (190) No Wedge Effect With Flat Seals	
Ability to Provide Axial Pressure Distributions Required for Pneumatic Bundling of 2 psi at Steady-State Provide Average Mechanical Bundling Pressure of 2.5 psi over Aft Six-Seventh Length of Core at Assembly							

NOMENCLATURE TABLE 7-4 PERFORMANCE CONSIDERATIONS REFLECTOR ASSEMBLY EC-677359		<div style="text-align: center;"> ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES </div>					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
(Lateral Support Seal Flow)							
Limit Axial Coolant Flow By-Passing Core to 0.63 ±0.09 lb/sec		(290)	(170)	(290)	(100)	(150)	
a) Core Bypass Flow Through Lateral Support Seal Segment		0.63 lb/sec	1.07 lb/sec	0.63 lb/sec	1.7 lb/sec	1.2 lb/sec	
b) Limiting Material Temperature		Moly Wrapper in Core Periphery 2000°R Nominal	Moly Wrapper in Core Periphery 2000°R Nominal	Moly Wrapper in Core Periphery 2000°R Nominal	Metal Bonds 1150°R Nominal	Moly Wrapper in Core Periphery 2000°R Nominal and First Spring Cell 1300°R Max 26°R	
c) Increase in Fuel Exit Temperature (Compared to Design Approach 1)		0°R	20°R	0°R	50°R		
d) Integrated Heat Flux to Structural Cylinder		2.72 MW	2.72 MW	2.72 MW	< 2.72 MW	< 2.72 MW	
Limit Maximum Temperature of Lateral Support Components to Acceptable Values		(210)	(120)	(210)	(250)	(210)	
a) Inner Seal Temperature		1385°R	1385°R	1385°R	1850°R	< 1385°R	
b) Outer Seal Temperature		1258°R	1258°R	1258°R	1500°R	< 1258°R	
c) Plunger Temperature		1285°R	1612°R	1285°R	None in Design Approach 4	1300°R	
d) Plunger Sleeve Temperature		None in Design Approach 1	2042°R (Unacceptable)	None in Design Approach 3	None in Design Approach 4	None in Design Approach 5	
e) Capsule Temperature		501°R	451°R	501°R	None in Design Approach 4	450°R	
f) Capsule Sleeve Temperature		771°R	617°R	771°R	None in Design Approach 4	600°R	
g) Spring or Band Temperature		931°R	1104°R	931°R	1150°R	1100°R	
Ability to Prevent Radial Leakage into Lateral Support Seal Region		(200)	(200)	(150)	(250)	(200)	
a) Leakage Along Capsule		O-Ring Seal at Interface with Support Structure	O-Ring Seal at Interface with Support Structure	O-Ring Seal at Interface with Support Structure	No Capsule in Design Approach 4	O-Ring Seal at Interface with Support Structure	
b) Leakage Through Capsule		O-Ring Seal at Capsule Cap	O-Ring Seal at Capsule Cap	O-Ring Seal at Capsule Cap & Core Shell	No Capsule in Design Approach 4	O-Ring Seal at Capsule Cap	

NOMENCLATURE TABLE 3-5 PERFORMANCE CONSIDERATIONS REFLECTOR ASSEMBLY EC-677559		<div style="text-align: center;"> ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES </div>					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
(Interface Requirement)	Reactivity Effects Due to Material and Mass Difference	(.100) 0.00\$ <i>This Design Approach Is Considered Reference and All Others Are Compared to It</i>	(.200) + 0.75\$ <i>Addition of 115 lb Carbon in Lateral Support and 173 lb A-286 CRES in Reference Region</i>	(.100) 0.00\$ <i>No Significant Difference When Compared to Design Approach 1, Metal Added at Alt End of Reflector Has Negligible Nuclear Effects</i>	(.500) + 2.10\$ <i>Addition of 470 lb of Beryllium in Reflector and Reduction of 350 lb of A-286 CRES in Reflector Region</i>	(.100) - 0.04\$ <i>Addition of 100 lb A-286 CRES in Springs and a Reduction of 18 lb of Carbon in Lateral Support Region</i>	
	Drum Span Effects Due to Material and Mass Difference	(.150) - 0.00\$	(.090) - 0.20\$	(.130) 0.05\$	(.500) + 1.60\$	(.130) - 0.05\$	
	Photon Source Strength (MeV/sec)	(.240) 3.92×10^{17} <i>Reference Design Mass Distribution</i>	(.190) 5.63×10^{17} <i>Increase of Graphite and CRES in Lateral Support Region</i>	(.240) 3.92×10^{17} <i>Same as Reference Design</i>	(.080) 13.50×10^{17} <i>Springs and Plungers Replaced With Metal Bonds Which Allow for Increased Mass of Beryllium</i>	(.250) 3.88×10^{17} <i>Small Difference in Mass Distribution When Compared to Reference Design</i>	
	Relative Shield Weight	(.200) 0.0 Lbs.	(.200) + 4.0 Lbs. <i>No Significant Difference</i>	(.200) 0.0 <i>No Significant Difference</i>	(.200) - 21.0 Lbs. <i>No Significant Difference</i>	(.200) + 2.0 Lbs. <i>No Significant Difference</i>	
	PERFORMANCE AVERAGE EMPHASIS FACTOR	.200	.193	.202	.184	.219 ▲	

W59776-1

NOMENCLATURE TABLE 3-6 WEIGHT CONSIDERATIONS REFLECTOR ASSEMBLY EC-677559		<div>Ⓢ</div> ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
OBJECTIVE: To Minimize Weight	Differential Weight (Compared to 957 lb Lateral Support Com- ponent Weight in Design Approach 1)	(230) 0 lb Design Approach 1 (Reference Design)	(161) +288 lb Addition of 115 lb Carbon in Lateral and 173 lb A-286 CRES in Reflector Region	(202) +108 lb Weight based on 6 lb Additional Weight Per Lock Mechanism	(199) +120 lb (Maintaining 54.00 in. NSS O.D.) Addition of 470 lb of Beryllium and Reduction of 350 lb of A-286 CRES in Reflector Region	(208) +82 lb Addition of 100 lb A-286 CRES in Springs and a Reduction of 18 lb of Carbon in Lateral Support Region Spring size increased to obtain desired g load capability.	
	WEIGHT AVERAGE EMPHASIS FACTOR	.230 ▲	.161	.202	.199	.208	

W5077A-1

NOMENCLATURE TABLE 3-7 DEVELOPMENT & QUALIFICATION CONSIDERATIONS REFLECTOR ASSEMBLY - EC-677559		ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
OBJECTIVE Reduce Development Time & Cost	NRX-A Experience	(275) NRX-A6 Lateral Support System Utilized a Guided Plunger and Angled Seal Segment Design Similar to Design Approach 1	(225) Plunger and Angled Seal Technology Applicable to Parallel Angle Seal with End Guided Plungers	(200) Similar to NRX-A6 Except That AF1 End Equipped with Core Lock Mechanism	(050) NRX-A Experience Not Directly Applicable to Keyed Seals and Metal Bands	(250) NRX-A1 Thru A5 Flat Seal & Plunger Technology Applicable to Wedged Seal With End-Guided Plunger	
	Material Availability	(200) Aluminum and Graphite Readily Available. A-286 CRES is Specialty Item Having a Long-Lead Time	(200) Same as Design Approach 1	(200) Same as Design Approach 1	(200) Same as Design Approach 1	(200) Same as Design Approach 1	
	Manufacturing Technology	(202) Manufacturing Technology Similar to NRX-A6	(202) Same as Design Approach 1	(202) Same as Design Approach 1	(192) Corrugated Metal Bands Not Used in Previous Reactors	(202) Same as Design Approach 1	
	Cost (Includes Reflector Structure and Beryllium Segments)	(210) \$1,007,120	(191) \$1,083,002	(198) \$1,053,062	(203) \$1,030,373	(198) \$1,052,736	
	Assembly and Shipping Techniques	(210) Similar to NRX-A6 Except for Techniques Associated with Capsules and Capsule Seals	(210) Same as Design Approach 1	(180) Core Lock Mechanism Requires Development of New Assembly and Shipping Techniques	(100) Special Assembly Techniques Required for Metal Bands	(300) Same as Design Approach 1	
DEVELOPMENT & QUALIFICATION AVERAGE EMPHASIS FACTOR		.219	.206	.196	.149	.230 ▲ •	

W59778-1

NOMENCLATURE TABLE 3-8 SCHEDULE CONSIDERATIONS REFLECTOR ASSEMBLY EC-677559		ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS		Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
OBJECTIVE: Meet R-1 Test Date of October 15, 1973	Time to Develop Lateral Support System (Compared to Reference Design Approach 1)	(.200) Must Develop Materials and/or Coatings or Impregnation to Assure Low Values for Coefficient of Friction	(.200) Must Develop Parallel Angled Seals and End Guided Plungers	(.125) Same as Design Approach 1 Plus Additional Time Required to Develop Core Lock Mechanism	(.125) Time Required to Develop Keyed Seals and Metal Bands	(.150) Time Required to Develop Wedged Seals and End Guided Plungers	
	Manufacturing and Material Procurement Time	(.207) 29 Weeks Seal Segment Procurement Time	(.207) Same as Design Approach 1	(.207) Same as Design Approach 1	(.172) 34 Weeks Corrugated and Flap Band Procurement Time	(.207) Same as Design Approach 1	
	SCHEDULE AVERAGE EMPHASIS FACTOR	.203	.203	.166	.148	.278 ▲ •	

NOMENCLATURE TABLE 3-9 MATRIX SUMMARY REFLECTOR ASSEMBLY EC-677559		Weighting Factor	<div> ASTRONUCLEAR LABORATORY COMPARISON MATRIX OF DESIGN APPROACHES</div>					SELECTION
FUNCTIONAL & TECHNICAL DESIGN REQUIREMENTS			Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4	Design Approach 5	
	Reliability and Safety	.30	.0273	.0867	.0225	.0432	.1203	
	Performance	.25	.0500	.0482	.0505	.0465	.0548	
	Weight	.25	.0575	.0403	.0505	.0497	.0520	
	Development and Qualification	.10	.0219	.0206	.0196	.0149	.0230	
	Schedule	.10	.0203	.0203	.0168	.0148	.0278	
	FIGURE OF MERIT	1.00	.1770	.2161	.1999	.1691	.2779	<div>▲</div>

4.0 SELECTION OF DESIGN

4.1 SUMMARY OF REASONS FOR SELECTION

As a result of this trade study, the wedged seal with end-guided plunger design approach was selected for detail design and development for the R-1 Nuclear Subsystem. The selected concept, Design Approach 5, received a figure of merit of .2779 in the overall evaluation summarized in the comparison matrix of Section 3.0. Design Approach 5 showed a distinct superiority in the reliability, performance, development, and schedule considerations outlined in the comparison matrix. The weight consideration is the only category where this approach was not superior. When compared to Design Approach 1, which was superior in the weight consideration, Design Approach 5 exhibited a small weight penalty of 82 lbs. The weight penalty is due to the increased spring size required to provide the desired g load capability. An increased spring force is required for a flat seal lateral support system due to the decreased wedge action.

The following is a summary of the key reasons for selecting a lateral support system utilizing the basic features of Design Approach 5:

- (1) The design provides the most flexibility for development of a lateral support system that will satisfy the requirements defined in the Reflector Assembly Specification, No. EC-677559.
- (2) The end-guided plunger combined with the flat seal configuration provides the capability of operating with a graphite coefficient of friction approaching 1.0.
- (3) The end-guided plunger eliminates high bending stresses associated with guided plunger designs.
- (4) The wedged flat seal concept provides for positive seating of the inner seal to the outer seal.

- (5) The design utilizes the plunger and flat seal technology developed for the NRX-A1 through A5.
- (6) The time required to develop this design is minimized due to its ability to function with high graphite friction.
- (7) The design uses materials and fabrication techniques that were developed for the NRX-A series reactors.
- (8) The flat seal and end-guided plunger features simplify assembly.

The selected design approach is a result of extensive design effort to develop a lateral support system insensitive to friction lockup without penalizing the sealing and support functions. Although there is some loss in load capability when compared to the reference design, much of this can be recovered by optimizing the spring force at each axial station. Further gains may be obtained from the keyed effect already present in the design. The sealing capability should be improved due to the flat seals and low probability of seal separation due to friction lockup on the core.

The selected design approach does not require an extensive materials development program to develop graphite materials having a reliable low coefficient of friction for a wide range of environmental conditions. All components are made from materials previously used in the NERVA program.

As part of the continued development of the lateral support system utilizing the basic concepts of Design Approach 5, the following recommendations are made:

- (1) An early test utilizing a partial length lateral support system should be conducted to provide detailed design data.
- (2) The benefits of keying should be studied by more detailed analysis and testing described in (1) above.

- (3) The length of the inner and outer seal segments should be optimized to reduce stresses resulting from thermal gradients, keys, and attachment hardware.
- (4) A full length vibration test simulating all core restraints should be conducted prior to R-1 assembly.

REFERENCES

1. DRM 51837 Manufacturing Engineering Supporting Data for Lateral Support System Trade Study, No. 782
2. DRM 52811 Systems Safety Supporting Data for Lateral Support System Trade Study, No. 782
3. DRM 52856 Radiation and Shielding Design Supporting Data for Lateral Support System Trade Study, No. 782
4. DRM 53045 System Reliability Supporting Data for Lateral Support System Trade Study, No. 782
5. DRM 53196 Modification of Materials Input to PDR Trade Study No. 782, Lateral Support, Data Item S-54
6. DRM 53370 Nuclear Supporting Data for Lateral Support System Trade Study, No. 782
7. DRM 53455 Structural Design Supporting Data for Lateral Support System Trade Study, No. 782
8. DRM 53589 Failure Mode Analysis for the Wedged Seal with End Guided Plunger Concept
9. DRM 53590 Failure Mode Analysis for the Locked Core Concept
10. DRM 53591 Failure Mode Analysis for the Reference Design
11. DRM 53592 Failure Mode Analysis for the Parallel Seal Concept
12. DRM 53593 Failure Mode Analysis for the Banded Seal Concept
13. DRM 53602 Quality Assurance Supporting Data for Lateral Support System Trade Study, No. 782
14. DRM 53640 Thermal Design Supporting Data for Lateral Support System Trade Study, No. 782

TITLE Lateral Support Trade Study, No. 782	
	DOCUMENT NO. WANL-TME-2763	DATE Dec. 1970
ABSTRACT <p>This document describes a trade study of design approaches of lateral support systems for the NERVA Nuclear Subsystem.</p> <p>The trade study evaluates and selects the order of preference of lateral support design approaches for continued design and development.</p>		
DATA ITEM NO. S-054		SECURITY CLASSIFICATION OF DOCUMENT [REDACTED]
CDRL LINE NO. TBD		TOTAL NO. OF PAGES 55
KEY WORDS <p>Requirements, Description, Evaluation and Selection of Design Approaches</p>		
AUTHOR/EDITOR Design Engineering/ H. D. Kulikowski		PREPARING DEPT. Reactor Design
W Form 59943		DOCUMENT INFORMATION SUMMARY

Fold
or Cut

Fold
or Cut