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INTERIM TRADE STUDY REPORT
POISON WIRE REMOVAL AND INSERTION ON GROUND
OCTOBER 1969 THRU FEBRUARY 1970

S054-1009

S054-CP-090290-F1

March 1970

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NERVA Program

Contract SNP-1

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ABSTRACT

During the first five months of CY 1970, a number of poison wire withdrawal/reinsertion device concepts were reviewed and evaluated with respect to the feasibility of each concept to provide a means of removing and replacing poison wires. The poison wires are inserted into the reactor core to guard against accidental criticality of the NERVA Engine.

In order to evaluate the poison wire concepts, a cursory functional flow diagram was prepared. The function of the wires during transportation, engine assembly, engine acceptance testing, stage assembly and checkout, and vehicle launch pad operations was then analyzed.

Based on this study and Government recommendations, not one, but three poison wire withdrawal/reinsertion concepts were suggested to perform these functions. The assumptions and requirements upon which this decision was based is described herein.

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I. INTRODUCTION

During Contract Year 1970, from October through February, the Poison Wire Withdrawal Devices were studied in conjunction with problems associated with anticriticality of the NERVA Engine for all ground handling operations.

This report documents the accomplishments in this area with regard to determination of requirements, assumed requirements, review of criticality safety hazards and description of poison wire withdrawal/reinsertion concepts.

A summary of this effort with conclusions and proposed future effort is presented in Section II along with a brief description of the program accomplishments.

A more detailed description of the program is presented in Section III, assuming checkout and prelaunch operations for a nuclear-powered third stage aboard a Saturn V launch vehicle. Potential criticality accident situations are identified and a summary of the consequences of the accidents are included. Section III also presents a detailed description of the poison wire withdrawal and reinsertion concepts considered and suggests further work to be done relative to this project.

Section IV contains the conclusions of this study.

This project has been deleted from the amended work statement dated 16 February 1970 and all effort in this area has been suspended for the remainder of this contract year.

II. SUMMARY

A. CONCEPT SELECTION

This report details the effort and considerations involved in identifying poison wire removal/reinsertion concepts which render a solution for poison wire handling for all operations involved in ground handling of the reactor or nuclear rocket engine from initial fabrication through preparation for vehicle launch.

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The approach used in this study was to examine the sequence of events, using a functional flow diagram (Figure 1) for all operations involving the nuclear engine from the time of engine assembly to the planned poison wire withdrawal prior to launch. Each functional event was examined to identify potential sources of criticality. For those events in which criticality accidents could occur, analyses were made to evaluate the optimum countermeasure that would eliminate criticality possibilities.

The results of this analysis in conjunction with the SNPO-C recommendations (Appendix A) may be summarized in the form of the following requirements for a poison wire withdrawal/reinsertion device.

1. Remove all poison wires for acceptance test.
2. Reinsert all poison wires post acceptance test (Nozzle removed).
3. Remove peripheral poison wires in VAB, remove central poison wires prior to launch.

A conclusion of this study is that performance of these requirements could be accomplished with greater efficiency by the utilization of three separate devices or one for each of the specified operations.

1. Sequential Poison Wire Withdrawal Concept, AGC Drawing No. 1136166 (Figure 2), has been suggested for the removal of all poison wires prior to engine acceptance test.
2. Retainer Concept, AGC Drawing No. 1137087 (Figure 3), utilized in conjunction with manual poison wire reinsertion post acceptance test with the nozzle removed.
3. Sequential Central Poison Wire Withdrawal Concept, AGC Drawing No. 1137850 (Figure 4)- For removal of peripheral wires in the VAB and central on the launch pad (with destruct subsystem in place).

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CRITICALITY SAFETY HAZARD
FLOW DIAGRAM

Figure 1 - Criticality Safety Hazard Flow Diagram

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Figure 3 - Poison Wire Retainer

Figure 4 - Poison Wire Withdrawal Assembly
(Launch Pad Operations)

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III. DISCUSSION

A. REQUIREMENTS

The NERVA Design Requirements Sheet specify the engine shall provide features for prevention of accidental criticality during all ground and flight operations prior to initial nuclear engine start-up. These requirements are derived from the NERVA Program Directive No. 18, dated 19 November 1969, which states that the NERVA Engine shall incorporate the following: "Means of preventing accidental criticality during all ground and space operations. An anticriticality destruct system shall be provided for launch and ascent".

This report is concerned primarily with the effort pertaining to an anticriticality poison wire withdrawal/reinsertion device.

B. CAUSES OF CRITICALITY

The means by which accidental criticality could occur include the following:

1. Reactor core flooding by LH_2 , water, or other hydrogenous materials.
2. Core compaction as a result of impact, explosion, fire, or other accident.
3. Control-drum runout by control system malfunctions, or by mechanical damage from impacts or explosions, or thermal damage as the result of fire.
4. External neutron reflection.
5. Water injection into the core, while attempting to contain or extinguish a fire.

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C. CONSEQUENCES OF CRITICALITY

The NERVA Joint Document (NJD) 19, dated August 1969, states:

1. Impact and immersion of the reactor in water may initiate:
 - a. A nuclear excursion with seven (7) times the energy release of the KIWI-TNT experiment.
 - b. Large radiation doses, greater than 10 rad whole body gamma (WBG) at distances within one mile from point of impact.
 - c. Reactor criticality and subsequent oscillations could increase the core multiplication factor and produce some fission power generation.
2. Impact of the reactor on land may initiate:
 - a. A nuclear excursion conservatively estimated at 0.6 times the KIWI-TNT energy release.
 - b. Radiation level 3.5 miles from impact point is estimated at 0.5 rad WBG.

D. PREVENTATIVE ACTION

The method selected for the prevention of criticality during all ground handling operations involved utilization of a neutron poison inserted in the reactor core coolant passages in the form of poison wires.

The problem associated with the poison wires depends on whether the wires must be removed for engine acceptance testing, the configuration of the engine at that time, and the test facility constraints imposed on the withdrawal device. Flexible poison wires are required to allow removal of the wires through the nozzle throat.

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Subsequent to acceptance testing, all or just the central poison wires may require insertion into the core depending on the location of the acceptance tests. The problems associated with reinsertion of all the poison wires is contingent on whether the nozzle may or may not be removed for this operation. For the case where the nozzle cannot be removed, the many thousands of poison wires must be reinserted through the nozzle throat. If the nozzle is removed for wire reinsertion than the integrity of the nozzle seal is subject to challenge.

Finally, the requirement for removal of all wires/central prior to vehicle launch as late in the count down as feasible may require manned access inside the skirt extension with the vehicle on the launch pad.

E. OBJECTIVE

The primary objective of this study is to select a Poison Wire Withdrawal Assembly design that will satisfy ground safety requirements and prevent, in the case of accident, the NERVA reactor from achieving criticality and presenting radiological hazards to personnel or populated areas.

Additionally the ancillary objectives of this study are:

1. Provide a withdrawal mechanism design.
2. Provide a reinsertion mechanism design.
3. Select the optimum attachment location.
4. Determine AGC/WANL interface.
5. Determine and coordinate the poison wire requirements from:
 - a. KSC Range Safety
 - b. Ground Safety
 - c. Acceptance Testing
 - d. System Requirement
 - e. System Integration

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F. ASSUMPTIONS

SNPO-C recommendations pertaining to poison wires as described in Memorandum EDB:CLC (Appendix A) dated May 23, 1969, subj: "Acceptance of NERVA Engine" and presented in part herein, was utilized as preliminary requirements for the current poison wire concept evaluation.

If certain of these assumptions are modified or are later proven to be invalid, the conclusion and recommendation of this study may require alteration.

The key assumptions from subject memorandum are as follows:

1. Preferred Operation

- a. CEI provisional acceptance at contractor plant.
- b. Module assembly and assembly checks at contractor plant.
- c. Shipment of modules and miscellaneous hardware to KSC for engine assembly/checkout/acceptance. Acceptance test planning is to include considerations for functional tests, leak tests, and operational tests such as cold flow, low power and transfer function tests. The intent will be to do as much testing during acceptance as possible and still permit safe handling of engine during subsequent operations.
- d. Mate engine/stage/ascent shell at KSC and perform acceptance tests on stage.
- e. Assume for above sequence of operations that the reactor is fully poisoned for module handling; all poison is removed for acceptance testing of engine; central poison is reinstalled for operations subsequent to acceptance; and that the central poison is removed prior to launch for all missions.

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2. Alternate Operation

- a. Same as 1.a. above.
- b. Same as 1.b. above.
- c. Same as 1.c. above except ship engine modules to Michoud and acceptance test engine at Mississippi Test Facility (MTF).
- d. Mate engine/stage/ascent shell at Michoud and perform stage acceptance test.
- e. Ship stage to KSC by barge.
- f. Perform receiving inspection at KSC and assemble on vehicle.
- g. Assume for above sequence of operation that the reactor is fully poisoned for module handling; all poison is removed for acceptance testing of engine; reactor is fully poisoned for shipment to KSC (assume nozzle removal for installation of poison); peripheral poison removed prior to vehicle assembly; and central poison removed prior to launch.

G. CRITICALITY SAFETY HAZARDS STUDY

To define and aid in the selection of the optimum NERVA engine safety countermeasure for prevention of criticality or radiological hazards, a Criticality Safety Hazard Study was initiated based on the assumed requirements specified and also the additional possibility of performing the engine acceptance test at the Nuclear Rocket Development Station (NRDS).

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A flow diagram, Figure 1, was developed which lists the major activities from initial reactor shipment through launch pad operations in time line sequence and also presents criticality failure modes, preventative action and selected safety methods. The justifications for the selected methods are presented herein with a brief summary of the consequences involved. The item numbers below correspond to the events illustrated on the flow diagram.

1. Engine Assembly Components are shipped from AGC, Sacramento to the Engine Assembly Site (TBD)

Nuclear safety precautions are not involved in this effort.

2. AGC will delivery the following components to WANL.

Pressure vessel, closure, pressure vessel bolts and seals and aft end shipping closure. Nuclear safety precautions are not involved in this effort.

3. Assembly of WANL Pressure Vessel and Reactor Assembly (PVARA)

During the pressure vessel and reactor assembly, the possibility of the following criticality safety hazards exist: drum rollout, core compaction (ground impact) and water injection into the core by the inadvertent release of water from a fire protection system. The preventative action options are: poison wire insertion, an air tight shipping container equipped with a shock absorbing material and control drum lock mechanism or a combination of a sealed shipping container including a gas or liquid poison. The selected method for this operation was poison wire insertion. The justification for this selection is based on the current utilization of poison wires although an air tight shipping container with shock mounts, poison and control drum lock mechanism would permit safe reactor delivery. If the latter method were selected, the poison capability of gas or liquid would involve a research and development program.

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3.a. Shipment to Engine Assembly Site

The engine assembly site has not been defined at this time. Kennedy Space Center (KSC), Michoud and NRDS were considered as potential engine assembly sites. The following safety hazards could exist during shipment: control drum rollout, core compaction due to ground impact, core flooding due to water immersion. The preventative actions are: poison wire insertion, a combination of an air tight shipping container with shock mounts and a control drum lock mechanism, or a combination of sealed shipping container and a gas or liquid poison. The selected method for this activity was poison wires since this is the current proven method and the other methods investigated do not appear to offer any significant advantages.

4. Engine Assembly and Receiving Inspection

The pressure vessel and reactor assembly will be inspected upon receipt in the receiving area. This inspection could present the following safety hazards: control drum rollout, core compaction due to ground impact, and water injection into the core. The preventative action options are: poison wire insertion or to perform the inspection remotely. The suggested method is to utilize poison wires that afford protection for the inspection crew since remote inspection of the equipment would be undesirable and costly.

5. Engine Assembly

It is assumed that the engine will be assembled either in the receiving inspection area or a separate engine assembly area. The following criticality safety hazards could be encountered: control drum rollout, core compaction due to ground impact and water injection into the core. The preventative action options are poison wires or remote assembly techniques. A remote assembly for the engine system is not practical and serves no useful function, therefore, utilization of poison wires was selected for this activity.

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6. Michoud and Mississippi Test Facility

The assembled engine will be transported from the Michoud assembly facility by barge to the Mississippi Test Facility, a distance of approximately 40 miles. During this transportation effort the following safety hazards exist: control drum rollout, core compaction due to ground (deck) impact, and core flooding due to water immersion. During transportation over water the core flooding hazard overshadows other considerations. The preventative action options are: poison wires, a combination of an air tight container with shock mounts and control drum lock mechanism, or a combination of the air tight container plus a gas or liquid poison. The selected method is poison wires. The justification for this selection is based on the assumption that an air tight container for the entire engine assembly would be impractical and serves no unique function.

7. Transport Engine to the Test Stand

The engine assembly from Michoud will be transferred from the barge to the test stand. Engine assemblies at the other sites will proceed to the test area by conventional transportation. The following safety hazards exist: control drum rollout, core compaction by ground impact and core flooding by water immersion or water injection into the core. (Note: cases of flash floods have been recorded at NRDS). The preventative action options are: poison wires or air tight shipping container with shock mounts and control drum lock mechanism. The suggested method is poison wires, largely for the reasons previously mentioned, i.e., an air tight shipping container for an entire engine would be cumbersome and expensive and solve no unique problem.

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8. Engine Acceptance Test

During engine acceptance test it is assumed that all the poison wires must be removed. The following safety hazards exist: control drum rollout, flood core with liquid H_2 , core compaction by impact to the ground and water injection into the core by an inadvertent spray from the test stand deluge system. The action to prevent criticality safety hazards requires performing the tests in a remote location.

9. Prepare Engine for Shipment

The post acceptance test engine handling techniques must be determined by the post test radiation levels. If the post test radiation levels are dangerously high, the engine must be removed from the test stand and handled with remotely operated equipment. The following safety hazards exist: control drum rollout, core compaction by impact and water injection into the core. The preventative action options are: poison wire reinsertion, an air tight container with shock mounts in combination with a control drum lock mechanism or a combination of the air tight container with a gas or liquid poison. The suggested method is contingent on the engine radiation level. The poison wire reinsertion as well as the air tight container would require complicated remote handling equipment. Until the post acceptance test radiation level is firmly established, a meaningful selection for this activity must be deferred.

In the event that radiological levels present no personnel danger, poison wire reinsertion would be the preferred preventative action.

If the wires are to be reinserted, a trade study is required to determine the most efficient method, e.g., removal of the nozzle versus a poison wire reinsertion device.

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10. Transport Engine to Stage Assembly Area

It is assumed that transportation to Kennedy Space Center from MTF will be by barge and by airplane from NRDS. The following safety hazards exist: control drum rollout, core compaction by impact and core flooding by water immersion. The preventative action options are: poison wire reinsertion, an air tight container with shock mounts in combination with a control drum lock mechanism or a combination of the air tight container with a gas or liquid poison. The suggested method is poison wire reinsertion.

11. KSC Stage Assembly

The engine can be assembled to the propellant tank in the vertical assembly building (VAB) or received this way from Michoud. The following safety hazards are present: control drum rollout, and core compaction from ground impact. The preventative action options are: poison wires or remote location. For protection of personnel working around the engine, it is advisable to select poison wires for this activity.

12. KSC Stage Checkout

The engine assembly may have functional, electrical and leak checks performed in the vertical assembly building or at Michoud. During this activity the following safety hazards exist: control drum rollout, core compaction by impact with the ground and water injection into the core by the fire sprinkler system. The preventative measures are: poison wires or remote handling location. The suggested method to prevent these hazards will be poison wires. The justification for this selected method was based on the fact that personnel are required in the area for the stage checkout.

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13. Transfer Stage to VAB

The stage if received from Michoud can be transferred to the vehicle assembly building. The following safety hazards exist: control drum rollout, core compaction by impact with the ground and core flooding by water immersion. The preventative action options are: poison wires or combination of central poison wires, control drum locks and filling in streams that must be crossed at the cape. The suggested method is poison wires. The justification for this selection is that it appears simpler to have a full complement of poison wires rather than fill in streams between the Receiving area and the vehicle assembly building.

14. Stage Assembled to Launch Vehicle

When the stage is assembled to the launch vehicle in the VAB the following criticality safety hazards exist: control drum rollout, core compaction and water injection into the core. The suggested preventative action is: poison wires. The justification for this selection is based on the fact that none of the other methods considered can be utilized at this time.

15. Transfer Vehicle to the Launch Pad

During the transfer of the vehicle to the launch pad the following safety hazards exist: control drum rollout, core compaction by ground impact and core flooding due to water immersion. The suggested preventative action option is utilization of poison wires. The justification for this selection is none of the other methods considered can be utilized at this time. If the peripheral poison wires are removed, the remaining central poison wires will protect against inadvertent drum rollout or compaction from ground impact but do not afford protection from core flooding.

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16. Prepare for Launch

During the launch pad operation, the following criticality safety hazards exist: control drum rollout, flooding the core with liquid H_2 or other propellants from Stage I and II, core compaction from ground impact and water injection into the core. Preventative action for this activity includes poison wires, destruct subsystem, nuclear self destruct and remote location. Based on the assumption that the poison wires are to be removed on the pad prior to launch a reactor destruct subsystem is required. Consideration should be given to the possibility that poison wires can be left inserted at launch. The safety aspects of a launch with poison wires, at this time, offers redundancy.

H. ACCOMPLISHMENTS

The poison wire withdrawal/reinsertion design concepts previously proposed by AGC were reviewed on the basis of the objectives states in Section III E, the safety hazards study and the SNPO-C instructions. This review resulted in the selection of six concepts, that can accomplish the objectives of this study, for further evaluation. Several new concepts, e.g., those concerned with poison wire withdrawal subsequent to destruct subsystems installation were also, generated.

A meeting of AGC and WANL personnel was held at Large, Pa. on 9 December 1969 to discuss the scope of the WANL Anticriticality Trade Study 719/029. It was established that this trade study is concerned only with anticriticality destruct requirements as related to flight safety. There currently was no provision in the trade study for establishing ground handling anticriticality requirements or evaluation of other flight anticriticality devices. As a result of this meeting, Interface Event Document 413 (Appendix B) Anticriticality System Interface between WANL and AGC was generated. This document required specific poison wire information and requested an interface determination meeting. The cancellation of effort in this area precluded establishing the WANL/AGC interface; a scheduled coordination

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meeting with the KSC Range Safety Personnel; determination of the optimum poison wire device location and compilation & assessment of the poison wire requirements from the various disciplines presented in part, as Ancillary Objectives for this study.

The flow diagram "Criticality Safety Hazards", a summary discussion of this diagram and the currently suggested poison wire concepts were presented to the NRD Safety Staff and the Reliability and Safety Analysis Section for their review. It was concluded that the safety requirement could be met by the proposed concepts.

I. ALTERNATIVES

The poison wire withdrawal/reinsertion design concepts considered capable of accomplishing some or all the requirements as specified in Section ____ are:

		<u>AGC Drawing No.</u>
1.	A device for removal of all poison wires prior to acceptance test. (Figure 2)	1136166
2.	A device for reinsertion of all poison wires post acceptance test (Nozzle in-place) (Figures 5 & 6)	1136485 1136292
3.	A method of replacing all poison wires post acceptance test (Nozzle removed) (Figure 3)	1137087
4.	A mechanism for replacing central poison wires (Nozzle in-place) (Figure 7)	1136502
5.	A device for removal of peripheral poison wires in the VAB and the central poison wires on the launch pad (Figure 2)	1136166
6.	A device for removal of all poison wires on the launch pad (destruct subsystem in-place). (Figure 4)	1137850

J. POISON WIRE WITHDRAWAL/REINSERTION CONCEPTS

1. Poison Wire Withdrawal

The concept shown in Figure 2 AGC Drawing 1136166 is proposed for the removal of all wires prior to acceptance test and/or peripheral wire withdrawal in the VAB and central poison wires removal on the launch pad.

Figure 5 - Poison Wire Withdrawal Device, Concept No. 53

Figure 6 - Tube Positioner and Guide Tube Replacement Device, Concept No. 13

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This layout drawing illustrates a difficult condition of poison wire removal, i.e., the engine in the vertical position and the skirt extension in-place. Where warranted the skirt extension may be removed and the engine positioned horizontally for accessibility and ease of handling. The approach to this problem is to find a solution using the most severe possible set of conditions and then simplifying the results where warranted. This design is based upon utilization of the Westinghouse Astronuclear Laboratory (WANL) designed flexible poison wires, poison wire retainer and cluster hot end support hardware shown in Figure 8. Modification of the WANL components will directly affect the withdrawal mechanism described below. In operation, a single lanyard (actuated by a lightweight motor) releases the retainer mechanism and sequentially withdraws the poison wire clusters. Each cluster contains six or eight poison wires and may be withdrawn manually or with a constant speed drive motor. The constant speed motor can satisfy WANL's request for a poison wire withdrawal rate of 2 inches/second or less, to protect the reactor. The motor is also equipped with a low torque friction-slip clutch that prevents damage to components if a retainer or wire "freezes". By choosing to withdraw the wires sequentially, the torque or force required for withdrawal is reduced more than one-hundred-fold as compared with simultaneous cluster withdrawal.

A rubber protective boot inserted in the throat is provided to prevent nozzle damage, during the withdrawal operation.

2. Central Wire Reinsertion Device

Design Concept, AGC Drawing No. 1136502, Figure 7, is concerned only with the removal and reinsertion of the central poison wires and does not require utilization of the WANL cluster hot-end support hardware, retainer lugs or flexible poison wires.

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Figure 8 - Poison Wire Retainer Mechanism Cross Section

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This concept utilizes rigid poison wires stored in individual guide tubes, in the forward end of a large structural cylinder inserted in the nozzle throat. The poison wires stored in the guide tubes align with the reactor coolant passages are driven or retracted by individual pushrods. The pushrods are connected to a piston located in the aft portion of the structural cylinder.

In operation, when the screw jack is operated it advances the piston which activates the pushrods and inserts the poison wires into the core. The rods are connected to the piston by a light press-fit and, in the event of binding, interference or hole misalignment, are automatically disengaged. The piston is actuated by a motor and screw jack arrangement which also regulates the wire insertion and withdrawal rate. Motor reversal withdraws the central poison wires and stores them in individual guide tubes for future utilization.

3. Complete Compliment of Wire Reinsertion Device

This design Concept, AGC Drawing No. 1136485, Figure 5, provides for the removal or reinsertion of individual poison wires into specific core-coolant-passages at any stage of engine or vehicle assembly, as long as the tube positioners and guide tubes remain intact and attached to the WANL cluster hot end support hardware. Prior to nozzle assembly, plastic tube-positioning-devices are attached to poison wire retainer lugs to guide the wires to specific core locations (the possibility that the tube positioners may have to be removed for engine acceptance testing is discussed in the following paragraph).

In operation, WANL flexible poison wires with extended stainless steel pigtails are individual inserted into the plastic guide tubes, manually or with a constant speed mechanical wire feeding device. In this manner, any individual wire feeding device. In this manner, any individual wire may be inserted or removed from the core coolant passages. Wire and tube will have to be color coded due to the differential length of the wires located in the center of the core as opposed to those at the extremities.

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4. Tube Positioner Attachment

Design Concept 13, AGC Drawing No. 1136292, Figure 6, provides a means of replacing tube positioners and guide tubes (as described above) that may require removal prior to engine acceptance testing. This technique may be performed with the skirt or skirt extension removed or when the engine is integrated with the stage. The tube positioners are reinserted by an extension grip tool and a portable platform. Some type of visual aid, e.g., closed circuit television or optics may be required. Once the tube positioners are in place, the poison wires can be reinserted into the core as described in Section III.I.4.

5. Poison Wire Reinsertion Nozzle Removed

This Design Concept 19, AGC Drawing No. 1137087, ^{FIG 3} Figure 3 is predicted on nozzle removal and manual wire reinsertion and provides the means of retaining rigid poison wires during shipping, engine assembly, acceptance testing, vehicle assembly, or launch procedures.

6. Poison Wire Withdrawal Launch Pad

This design, AGC Drawing No. 1137850, Figure 4, may be utilized for poison wire withdrawal with vehicle on the launch pad with the dual projectile destruct system Concept B, AGC Drawing No. 1219421, shown mounted in the nozzle. Modification of the sequential poison wire withdrawal device Concept 1, previously described in Section III.I.1. provides for poison wires removal with the vehicle on the launch pad and this destruct system in-place.

Provisions for a platform of some type must be included in the early planning for compatibility of this concept with the stage and interstage to provide access inside the skirt extension.

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K. FUTURE EFFORT

The future effort in this area includes establishing specific requirements with regard to mission, vehicle configuration, ultimate utilization and assembly procedures for the NERVA engine. Requirement changes or design modifications by WANL can seriously effect the Poison Wire Withdrawal/Reinsertion Device final selection.

Functional flow diagrams, requirements allocation sheets and time line sequence of events diagrams are mandatory items required prior to renewed effort for this project. These items will require coordination of Kennedy Range Safety, Aerojet and WANL safety personnel and the Systems Integration personnel.

The WANL/AGC poison wire interface must be established and documented prior to design concept reevaluation or initiation of new concepts. These concepts must be continuously evaluated for impact and the consequences imposed on other interfacing components.

Once the requirements for the poison wire withdrawal/reinsertion device has been firmly established, additional conceptual studies, failure mode analysis and reliability determination in conjunction with detailed environment, stress, loads and mass properties analysis must be performed prior to final concept/concepts selection.

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IV. CONCLUSION

The present study evaluated the problem of accidental criticality of the NERVA flight engine during the handling and operations occurring over the time period from initial shipment of the nuclear reactor up to the time of poison wire withdrawal prior to launch.

Based on this evaluation and compliance with the most recent SNPO-C instructions, three separate concepts rather than one are suggested as providing the most efficient method of accomplishing the requirements. The concepts are as follows:

- A. FOR THE REMOVAL OF ALL POISON WIRES (PRIOR TO ACCEPTANCE TEST).
Sequential Poison Wire Withdrawal Concept (AGC Drawing No. 1136166) has been proposed.
- B. FOR REINSERTION OF ALL POISON WIRES (POST ACCEPTANCE TEST OPERATION WITH NOZZLE REMOVED).
Performed Manually or Remotely Concept (AGC Drawing 1137087) provides a means of retaining the wires for shipment.
- C. FOR REMOVAL OF PERIPHERAL WIRES IN THE VAB AND CENTRAL ON THE LAUNCH PAD/OR ALL POISON WIRES ON LAUNCH PAD (WITH DESTRUCT SUBSYSTEM IN PLACE).
Poison Wire Withdrawal Assembly (Launch Pad Operations) (AGC Drawing No. 1137850) has been proposed for this operation.

The SNPO-C instructions indicate removal of the nozzle post acceptance test is acceptable for reinsertion of the poison wires. If this assumption is disputed, the poison wire concept ^{SUGGESTIONS} must be reevaluated.

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APPENDIX A
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SPACE NUCLEAR PROPULSION OFFICE

CLEVELAND EXTENSION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

21000 BROOKPARK ROAD, CLEVELAND, OHIO 44135

In reply refer
to: EDB:OLO

May 23, 1969

Dr. W. O. Wetmore, Manager - NRO
Aerojet-General Corporation
P. O. Box 15847
Sacramento, California, 95813

Attention: Mr. R. Evleth

SUBJECT: Acceptance of NERVA Engine

Dear Dr. Wetmore:

We understand that a Trade Study is in progress covering this subject; however, the results are not to be available for some time. In the meantime, the System Engineering functional analysis must proceed with certain assumptions. Government discussions on this subject resulted in the following recommendations for use during the functional analysis, and should not prejudice the final results of the Trade Study.

A. Preferred Operation

- (1) CEI provisional acceptance at Contractor plant.
- (2) Module assembly and assembly checks at Contractor plant.
- (3) Shipment of modules and miscellaneous hardware to KSC for engine assembly/checkout/acceptance. Acceptance test planning is to include considerations for functional tests, leak tests, and operational tests such as cold flows, low power and transfer function tests. The intent will be to do as much testing during acceptance as possible and still permit safe handling of engine during subsequent operations.
- (4) Mate Engine/Stage/Ascent Shell at KSC and perform acceptance tests on stage.

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Dr. W. O. Wetmore

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- (5) Assume for above sequence of operations that the reactor is fully poisoned for module handling; all poison is removed for acceptance testing of engine; central poison is re-installed for operations subsequent to acceptance; and that the central poison is removed prior to launch for all missions.

B. Alternate Operation

- (1) Same as (1) above.
- (2) Same as (2) above.
- (3) Same as (3) above except ship engine modules to Michoud and acceptance test engine at LTF.
- (4) Mate Engine/Stage/Ascent Shell at Michoud and perform stage acceptance test.
- (5) Ship stage to KSC by barge.
- (6) Perform receiving inspection at KSC and assemble on vehicle.
- (7) Assume for above sequence of operation that the reactor is fully poisoned for module handling; all poison is removed for acceptance testing of engine; reactor is fully poisoned for shipment to KSC (assume nozzle removal for installation of poison); peripheral poison removed prior to vehicle assembly; and central poison removed prior to launch.

At this time the System Engineering functional analysis and the resulting specifications and designs should reflect the above considerations.

(A) The Preferred Operation and (b) The Alternate Operation must both be considered because it will be some time before the actual decisions will be made as to how and where the operations will be performed.

Very truly yours,

R. W. Schroeder
Chief, SNPO-C

cc:

Dr. W. H. Esselman, WAKL (For Information Only)

Mr. M. K. Wright, WAKL

Mr. H. H. Hoffman, SNPO-C/ARO

Mr. W. S. Snapp, AGC/Cleveland

Mr. H. M. Carness, SNPO Pap/Sacramento