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DOCUMENT NO.

TI-696-220-012

COVER SHEET

DOCUMENT TITLE

Development of an Improved Actuator for ZrH Reactor Systems;
A Historical Reference

AUTHOR

L. E. Donelan

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SUPPORTING DOCUMENT

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PROGRAM TITLE

ZrH Reactor Development Program

DOCUMENT TITLE

DEVELOPMENT OF AN IMPROVED ACTUATOR FOR ZrH REACTOR SYSTEMS; A HISTORICAL REFERENCE

PREPARED BY/DATE

L. E. Donelan

DEPT

737-75

MAIL ADDR

TOO5

IR&D PROGRAM? YES ☐

NO ☐

IF YES, ENTER TPA NO. _____

APPROVALS

E. Matlin

DATE

7-7-71

O. P. Steele, III

7-8-71

DISTRIBUTION

ABSTRACT

* NAME	MAIL ADDR
Detterman, R.	LB03
Donelan, L.	TOO5
Kurzeke, W.	TOO6
Maki, L.	LB03
Matlin, E.	TOO5
Moss, T.	LB03
Nakae, T.	LB08
Steele, O.P.III	TOO5

The history of the Actuator for the ZrH Reactor system is presented. The present design status is summarized.

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The control system for the ZrH Reactor and its drive actuator were evolved from the SNAP 8 DS Reactor designs. The SNAP 8 DS actuator was designed in 1964-1967 and is described in TDR 10313, "Design of the 8DS Control Drum Actuator Motor"; TDR 12141, "S8DS Control Drum Actuator Technical and Data Manual"; ST0620NA0027, "Control Drum Actuator, Assembly, S8DS; and Assembly Drawing, S8DS-16020.

Changes to the 8DS coil winding and wiring design, and modifications to the hardware were made in 1967 in order to add redundancy of coil circuitry and increase the coil reliability by converting the coil conductor from chrome plated copper to Oxalloy 28 conductor. Coil connections were changed from series to parallel connection. The results of these changes are described in ST0620NA0057, "Control Drum Actuator, S8DR, Assembly of", and Dwg. S8DS 16074, "Actuator Assembly - Control Drum Drive (Improved)."

Tests were performed on this improved coil configuration on a mockup version of the actuators, TDR 12568, "S8DR Control Drum Actuator Oxalloy Wire Coil Test Bed Thermal Cycle Tests", by E. L. Gardner and W. G. Long. Coil investigation was performed to DTP-696-26-014 and reported at TR-696-26-014.

Three actuators were manufactured for Qualitification testing to DTP-568-26-001 and the results were reported as TI-568-26-010 and TR-568-26-001. One of these actuators, Dev. 013, was selected for continued testing, DTP-696-26-020 and the satisfactory conclusion was reported as TR-696-220-002.

In 1967 a requirement for a new generation of reactors which would need higher operating temperature control elements including actuators was established. This program, referred to as the Advanced ZrH Reactor Program funded studies for uprating the actuator and the reactivity control system. Investigations included coil material studies; DTP-696-26-013, TR-696-26-004, DTP-696-26-019, TR-696-26-019, DTP-696-26-025, TR-696-26-025, DTP-696-26-016, TI-696-59-003, TI-696-59-004, and TDR 12723. Other tests were run to determine if Armco magnetic iron could be a replacement for Hiperco 27 magnetic iron, as the latter was very brittle; also if there was a time at temperature effect for the two materials. These tests are documented in DTP-696-26-021, TR-696-26-021, DTP-696-26-015, TR-696-26-015, TI-696-26-006, and TI-696-26-007.

The Advanced ZrH Reactor actuator design was proceeding on limited engineering effort prior to 5-13-1968, when the Project Office issued an IL with the latest reference design information leading up to a conceptual design review. A preliminary review was held and an IL was issued by L. Maki on 5-22-68, containing conceptual

design information on performance, configuration, reactor and drum materials, and temperature. The reference design was based on Eu_2O_3 Poison and a BeO reflector drum. A calculation of drum bearing stresses was made and reported (TI-696-26-018) on 11-12-68. On 12-10-1968, L. Maki issued an IL containing the reference drawing and report breakdown. Based upon the vibration loads and thermal stresses, TI-696-41-009 and TI-696-26-023 were issued. A bearing test program, TI-696-26-024 and DTP-696-26-004, was established.

At the end of 1968 a number of IL's were released documenting the S8DR actuator stress calculations, performance, and history. These IL's are generally applicable to the Advanced ZrH actuator, and are numbered as follows: TI-568-22-039, 568-22-040, 568-22-041, 568-22-042, 568-13-005, 568-22-032, 568-22-033, 568-22-034, 568-22-035, 568-22-036, 568-22-037, 568-22-038, and 568-22-043. Tentative wire and process specifications for the ZrH actuator were made (TI-696-26-010 and STO613NA0051).

By the first part of 1969 it was recognized that major changes to the S8DS actuator would be required due to the heavier drum, shock and vibration loads, lower gear ratio, the confines of the shielding requirements, and other factors necessary for an overall compatible system as specified in EC696N26003. Investigations were started, based on the vibration loads imposed by the launch vehicle TI-696-13-028 to determine the loads and stresses imposed on the drum and bearings, (TI-696-26-021, TI-696-26-029, TI-696-26-018), the material selections (NAA-SR-12045 and NAA-SR-12557) and testing of the bearings (AI-AEC-TDR-12775 and AI-AEC-TDR-12725), selection of drum materials, (TSR-696-26-001 and TI-696-26-026) as well as the thermal design (TI-696-26-017 and TI-696-22-002). The resulting first design, known as Drum No. 1, loads on the actuator were calculated (TI-696-26-028) and this drum was tested to shock and vibration (TR-696-26-026).

In March 1969 a study was made to evaluate the use of the actuator and brake to restrain the drums during vehicle launch. The dynamic loadings on the drum were published (TI-696-22-001 and TI-696-13-028) and this resulted in alternate locking systems being investigated (TI-696-26-027).

Project review of the data presented, resulted in direction to study the capability of increasing the actuator holding brake torque. This study was presented (TI-696-26-033) and the resulting decision was to concentrate on the locking pin and slot arrangement.

An actuator drive capability meeting was held in May 1969 and reported as TI-696-26-036 and DRR-696-13-002. The details of the actuator changes for the ZrH application were reviewed and instructions given to investigate reductions in drum weight. During this time some

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actuator work was continuing that resulted in two reports, TI-696-26-034 and TI-568-26-008. This latter report was of interest, due to the mechanical failure of Actuator Dev. 011.

In the latter half of 1969 considerable work was performed to obtain a lighter control drum to be known as Control Drum No. 2, as well as determining the expected and allowable drive tolerances. The weight reduction study was published as TI-696-13-039, TI-696-26-043, and Test Procedure DTP-696-26-022.

The final calculations and status for the drive system were published in a report TI-696-22-003.

The completed drive with Control Drum No. 1 (the heavier drum) was tested in June 1971 under shock and vibration conditions specified in EC696N26003 for the SNAP system. The satisfactory results of this test were published as TR-696-220-052. The tested actuator is described on EX-N69626164.

Refer to TI-696-220-011 for a detailed bibliography of all available reports and drawings applicable to the Advanced Actuator.

SUMMARY

The results of the investigation and testing to date can be summarized as follows:

1. The advanced actuator, as described on EX-N69626164 is resistant to shock and vibration (TR-696-220-052) in the radial direction and will probably be suitable in the axial direction to the requirements of EC696N26003.
2. Testing to determine an improved conductor resulted in the conclusion that Oxalloy 28 was still the best conductor (TR-696-220-002-01). Operation at 1200F for 20,000 hours as specified in EC696N26003, may require a ductile homogeneous high temperature conductor such as stainless steel. Other applications (temperature or life) will have a conductor material selected on the basis of the specific requirements as described in the above Test Report.
3. Some minor constructional changes are desired in the brake housing and are referenced in TR-696-26-002.

It is feasible with the above modifications to produce an actuator to meet the requirements as specified in EC696N26003.

APPENDIX "A"

INTERNAL SECURITY
ATOMIC ENERGY COMMISSION
- Office of Reactor Research and Development

TO	Design Review Board	DATE	May 22, 1968
ADDRESS		FROM	L. M. Maki
		ADDRESS	715-51
		PAGES	2562
SUBJECT	Conceptual Design of the Reference ZrH Reactor		
REFERENCE	IL to Those Listed from R. F. Wilson, "Advanced ZrH Reactor," dated May 13, 1968		

The Reference IL stated that a conceptual design review of the Reference ZrH Reactor would be held during the next few weeks. Due to budgetary and programmatic constraints, the design review has been delayed until next fiscal year.

A preliminary selection of the design review board was made, however, and partial data packages prepared. The attached data package is for your informal review prior to the design review which will be scheduled at a later date. If you have any questions, comments, or desire additional information, please feel free to contact me.

L. M. Maki
L. M. Maki
Assistant Project Manager
ZrH Reactor Technology

LM:evf

Attachments

Distribution attached

11/2

PERFORMANCE MAP - REF ZrH REACTOR

8-M21-048-12

REF. ZrH REACTOR REACTIVITY - LIFETIME (600 kwt)

8-M22-048-24

REFERENCE DESIGN CONTROL DRUM

REFERENCE REACTOR MATERIALS SELECTION

- FUEL
- HYDROGEN BARRIER
- BURNABLE POISON
- FUEL CLADDING
- COOLANT
- CORE VESSEL AND PIPING
- CONTROL DRUM
 - REFLECTOR
 - POISON
- CONTROL DRUM STRUCTURE
- CONTROL DRUM BEARING BALL
- BEARING SURFACES
- BEARING STRUCTURE
- ACTUATOR-STRUCTURE
- COIL-ENCAPSULANT

ZrH-10.5% U

SCB-1

Gd-155

HASTELLOY-N (INCOLOY 800 BACKUP)

NaK-78

316 STAINLESS STEEL

BcO OR Be

60 v/o Eu_2O_3 IN Ni

Nb-1.0 Zr

P-5 CARBON GRAPHITE

Al_2O_3

INCONEL X OR Ta-10W

HYPERCO 27 OR ARMCO IRON

AI-1 AND OXALLOY OR CUBE ALLOY

8-M21-048-13

CONTROL DRUM TEMPERATURES

	POWER (kw)	MAXIMUM BeO	MAXIMUM POISON	MAXIMUM CAN
POISON IN	600	1500	1570	1510
POISON OUT	600	1450	1420	1385
POISON IN	1200	1730	1830	1710
POISON OUT	1200	1700	1640	1580

ZrH REACTOR REFERENCE DESIGN

8-A30-075-2

REFERENCE ZrH REACTOR

Upper Bearing

TEMPERATURES, OF

Node 600 kw 1200 kw

1	1270	1345
2	1272	1351
3	1274	1354
4	1273	1356
5	1250	1324
6	1222	1206
7	1205	1254
8	1100	1207
9	1165	1173
10	1279	1371
11	1150	1150

REFERENCE Zr H REACTOR

Lower Bearing

TEMPERATURES, °F

NODE 600Kwt 1200Kwt

1	1270	1345
2	1274	1354
3	1271	1350
4	1259	1333
5	1226	1285
6	1217	1277
7	1184	1216
8	1150	1150
9	1250	1319

REFERENCES

1. NAA-SR-MEMO-12522, Vol I, "Advanced SNAP Reactor, Technical Requirements and Reactor Capabilities," Oct. 20, 1967 (C-RD)
2. TSR-696-28-001, "Burnable Poison Selection for the Reference ZrH Reactor," E. H. Ottewitte, Apr. 5, 1968 (C-RD)
3. TI-696-13-003, "Normalized Control Drum Worth for the Reference ZrH Reactor," H. Rood, Feb. 1, 1968 (C-RD)
4. TI-696-28-003, "Fuel Swelling Model for Use in the Reference ZrH Reactor Design," L. D. Swenson, Apr. 8, 1968 (C-RD)
5. TI-696-13-001, "Variable Cross Section Treatment of Gd-155 in the Reference ZrH Reactor," H. Rood, Dec. 19, 1967
6. TI-696-13-006, "Reactor Design Evolution, Reference ZrH Reactor," H. E. Richter, Jr., Feb. 26, 1968
7. AI-AEC-12641, "SNAP Programs Progress Report, Nov 1967 - Jan 1968," R. L. Detterman, March 20, 1968 (C-RD)

APPENDIX "B"

INTERIM REPORT
PROGRESS OF THE PROJECT
ADVANCED DEVELOPMENT AND
AEROSPACE NUCLEAR SAFETY

DATE December 10, 1968

TO Those Listed
FROM

SUBJECT L. M. Maki
715-51, BE03

PAGE 2562

SUBJECT Preliminary Design of the Reference ZrH Reactor

We are committed to complete the preliminary design of the Reference ZrH Reactor this fiscal year. The design and development efforts in support of this system have proceeded to the point where definitive assignments can be made which will permit us to meet this milestone.

A drawing breakdown tree (N696 20005) is provided for your guidance. This is a standard "goes into" tree and includes only the reactor assembly. The shield and primary loop portions of the overall reactor system will be covered later. The first three or four tiers of drawings constitute the preliminary design of the reactor and will be prepared prior to the design reviews which will be held in April. The remaining drawings on the tree are indicative of those which will be required to complete the detail design, but should not be considered to be firm requirements at this time.

The schedule and the responsibility for preparation of the preliminary design drawings are given in Attachment #1. The scheduled completion dates are intended to provide a complete set of drawings for the design reviews to be held in April. The base drawing, from which the design will develop, is N696 13034.

Attachments #2, 3, 4, and 5 provide preliminary guidance for the preparation of design review data packages. These are intended as the minimum requirements for the drawings, specifications, and analytical backup which should be completed prior to scheduling the design reviews. The appropriate project engineers should make sure that their planning includes the preparation of this documentation. The PERT charts for the various subaccounts should be updated to include this level of detail. The specific schedule for the design reviews will be provided at a later date.

L. M. Maki
Assistant Project Manager
Advanced Development and
Aerospace Nuclear Safety

Attachments (7)

ZrH Reactor Design Schedule

	<u>Requirements</u>	<u>Design</u>	<u>Completion Date</u>
1. Reactor - Reference Design Drawing	P	N	Completed
Reactor Assembly	P	N	4-1
2. Reactor Vessel & Control Drum Assembly	N	N	3-15
Core Assembly	N	N	3-15
Actuator & Drive Assembly	N	N	3-15
3. Reactor Vessel & Reflector Assembly	N	N	1-30
Reactor Head & Drywell Assembly	N	N	2-28
Reactor Vessel Manifold Assembly	N	N	2-28
Inner Reflector Assembly	N	N	2-28
Outer Reflector Assembly	N	N	2-28
4. Control Drum & Support Assembly	N	N	1-30
Control Drum Assembly	N	M	2-28
Bearing Assembly-Lower	N	M	2-28
Upper Support & Bearing Assembly	N	M	2-28
5. Core Vessel Assembly	N	N	1-30
Fuel Element Assembly	N	M	1-30
Internal Reflector Assembly No. 1	N	N	2-28
Internal Reflector Assembly No. 2	N	N	2-28
6. Drive Gear Assembly	N	M	2-28
Actuator Assembly	N	(M)	2-28
Actuator Support Assembly	N	(M)	2-28
7. Wiring Harness	N	N	3-15

P = Project

N = Nuclear Engineering Dept.

M = Materials & Component Engineering Dept.

Reactor Assembly Design Review Package

Drawings

N69620001 Reactor Assembly
N69620002 Reactor Vessel & Control Drum Assembly
N696 Core Assembly, ZrH Reactor

Specifications

SS696N0001 ZrH Reactor
SS696N07001 Environmental Requirements
(also subsystem specifications)

Analysis Reports

ZrH Reactor Nuclear Performance
ZrH Reactor Thermal Performance
ZrH Reactor Launch Loads
ZrH Reactor Design Data Sheets
ZrH Reactor Hydraulic Performance
ZrH Reactor Materials Selections
ZrH Reactor Q A. Program Plan

Reactor Vessel Design Review Package

Drawings

N69620001	Reactor Assembly
N69620002	Reactor Vessel & Control Drum Assembly
N69620003	Reactor Vessel & Reflector Assembly
N69621011	Reactor Head & Drywell Assembly
N696	Reactor Vessel Manifold Assembly
N69626027	Inner Reflector Assembly
N69626033	Outer Reflector Assembly

Specifications

SS696N.0001	ZrH Reactor Vessel & Structure
SS696N.7001	Environmental Requirements Electrical Discharge Machining Process

Analysis Reports (TI's)

Reactor Vessel Materials Selection
Reactor Startup Transient Analysis
Steady State & Transient Thermal Analysis
Steady State & Transient Thermal Stress Analysis
Reactor Launch Loads & Stress Analysis
Reactor Vessel Fabrication Methods
(others as required)

Core Assembly Design Review Package

Drawings

N69620001	Reactor Assembly Core Assembly Core Vessel Assembly
N69624018	Fuel Element Assembly Internal Reflector Assembly No. 1 Internal Reflector Assembly No. 2

Specifications

SS696N20001	ZrH Reactor
SS696N17001	Environmental Requirements Core Assembly
EC696N24001	Fuel Element

(also materials & process specifications)

Analysis Reports

ZrH Reactor Nuclear Performance
ZrH Reactor Lifetime Predictions
ZrH Reactor Thermal Performance
Fuel Element Spacing Selection
Grid Plate & Vessel Stress Analysis
Fuel Element Performance Data Summary
Fuel Element Shock & Vibration Behavior
Status of Burnable Poison Development

Reflector and Drive Design Review Package

Drawings

N69620001	Reactor Assembly
N69620002	Reactor Vessel & Control Drum Assembly
N69620006	Control Drum & Support Assembly
N69626007	Control Drum Assembly
N69626065	Bearing Assembly-Lower
N69626018	Upper Support & Bearing Assembly
N69626039	Actuator & Drive Assembly
N69626074	Wiring Harness
N69626059	Drive Gear Assembly
N69626040	Actuator Assembly
N69626062	Actuator Support Assembly

Specifications

SS696N20001	ZrH Reactor
SS696N17001	Environmental Requirements Reflector & Drive System
EC696N26001	Control Drum
EC696N26002	Bearings
EC696N26003	Actuator

(also Materials & Process Specifications)

Analysis Reports (TI's)

Control Drum Poison Material Selection
BeO Material Selection
Bearing Materials Selection
Actuator Materials Selection
Thermal Design of the Control Drum
Thermal Stress Analysis of the Control Drum
Launch Stress Analysis of the Control Drum
Preliminary Results of Compatibility Testing
Bearing Thermal-Mechanical Performance
Control Drum Lockout Device Selection
Actuator Performance Capabilities
Status of Coil and Magnetic Materials Tests