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ROCKET ENGINE OPERATIONS - NUCLEAR

REPORT NO. RN-S-0062

TO

AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

TPA PRESENTATION, SNPO-C
(u)

25, 26 FEBRUARY 1964

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by authority of _____
by _____ TIC, date SEP 10 1973

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NOTICE

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RESTRICTED DATA—ATOMIC ENERGY ACT 1954

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SPEC. DETERMINATION	Class.	Date
	U	2-24-64

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NERVA ENGINE PERFORMANCE
MEETING AGENDA

FEBRUARY 25 & 26, 1964

Speaker

1.0	<u>AGC PRESENTATION</u>	
1.1	INTRODUCTION	C. H. Trent
	1.1.1 Material to be presented	
1.2	TURBOPUMP PERFORMANCE	S. R. Andrus
	1.2.1 Review of Mark III TPA Test History	
	1.2.1.1 Straight Inlet	
	1.2.1.2 First Center Bodied Inlet Line	
	1.2.2 Review of Mark III Mod. 4 TPA	
	1.2.3 Summary of Mark III Mod. 3 Impeller Failure	
1.3	ENGINE OPERATION, STEADY STATE	B. Mandell
	1.3.1 Description of System Configuration	
	1.3.2 Engine Steady State Operating Map	
	1.3.3 Engine Operating Constraints	
	1.3.3.1 Mark III TPA	
	1.3.3.2 Mark XV TPA	
1.4	ENGINE CONTROL SYSTEM	E. L. Kornfeld
	1.4.1 Description of System Configuration	
	1.4.2 Engine System Dynamics for Mark III TPA	
	1.4.3 Start-up Stability for Mark III TPA	
1.5	ANALOG MODEL COMPARISONS	M. Goldman
1.6	CONCLUSIONS	W. D. Stinnett

LIST OF PRESENTATION CHARTS
NERVA ENGINE PERFORMANCE

FEBRUARY 25 & 26, 1964

1.2 TURBOPUMP PERFORMANCE

1. Mark III TPA LH_2 Pumping Performance - Δp vs $\dot{w}$, Straight Inlet
2. Mark III TPA LH_2 Pumping Performance - $\Delta H/\text{N}_2$ vs Q/N , Straight Inlet
3. Mark III TPA LH_2 Pumping Performance - NPSP vs $\dot{w}$, Straight Inlet
4. Mark III TPA LH_2 Pumping Performance - $\Delta H/\text{N}_2$ vs Q/N , Center Bodied Inlet
5. Mark III $\frac{1}{2}$ TPA, Modification Description
6. Mark III - Mark III $\frac{1}{2}$ Performance Comparison, Δp vs $\dot{w}$

1.3 ENGINE OPERATION, STEADY-STATE

7. Hot Bleed Cycle Schematic Diagram - XE Engine
8. Steady-State Operating Map - Stall Constraint at $Q/\text{N} = 0.2$
9. Steady-State Operating Map - Mark III Pump Stall and Cavitation Constraints for 2 and 4 psi NPSP at Design Conditions
10. Steady-State Operating Map - Mark XV Pump Stall and Cavitation Constraints for 2 and 4 psi NPSP at Design Conditions

1.4 ENGINE CONTROL SYSTEM

11. Basic Control Loop Block Design
12. Normal Start-up Profile
13. Start-up Transient - Pump Water Data
14. Start-up Transient - Pump Water Data
15. Start-up Transient - Pump Water Data
16. Start-up Transient - LH_2 Straight Inlet Data
17. Start-up Transient - LH_2 Straight Inlet Data
18. Start-up Transient - LH_2 Straight Inlet Data

19. Operating Map With Stability Points Analyzed

20.-31. Response to Flow Disturbance

20.	Tie Rod 1000 ⁰ R, P _c 410, T _c 4090	Fixed Valve
21.	" " " 410 4090	Closed Loop
22.	" " " 220 3000	Fixed Valve
23.	" " " 220 3000	Closed Loop
24.	" " " 90 2000	Fixed Valve
25.	" " " 90 2000	Closed Loop
26.	Tie Rod 1200 ⁰ R, P _c 280, T _c 4090	Fixed Valve
27.	" " " 280 4090	Closed Loop
28.	" " " 155 3000	Fixed Valve
29.	" " " 155 3000	Closed Loop
30.	" " " 50 2000	Fixed Valve
31.	" " " 50 2000	Closed Loop

HOT BLEED CYCLE SCHEMATIC DIAGRAM

XE ENGINE (u)

FULL POWER CONDITIONS

Overall Engine Thrust, lb 54,030
 Main Thrust Chamber Thrust, lb 52,310
 Turbine Exh. Noz. Thrust Axial, lb 1,720
 Overall Engine Specific Impulse, sec 731
 Chamber Specific Impulse, sec 747
 Turbine Nozzle Specific Impulse, sec 440
 Turbine Exhaust Nozzle Area Ratio 9

PARAMETER SCHEDULE AT FULL POWER

Station	$\dot{W}$ lb/sec	p psia	T °R	BTU/sec
1	74.7	20.6	36.5	
2	74.7	16.8	36.5	
3	74.7	948	49	
4	74.7	941	49	
4a				
5	74.7	747	164	
6	74.7	698	236	
7	71.5	676	246	
8	71.5	550	4090	
9	70.0	550	4090	
10	2.45	698	236	
11	2.45	690	420	
12	1.5	548	4090	
13	3.95	547	1940	
14	3.95	544	1800	
15	3.95	352	1800	
16	3.95	38.0	1510	
20	.75	698	236	

GROUP-1
 EXCLUDED FROM AUTOMATIC DOWNGRADING
 AND DECLASSIFICATION
RESTRICTED DATA
 ATOMIC ENERGY ACT OF 1954

$\eta_p = .68$
 $\eta_T = .356$
 $\eta_N = .96$
 $C_F = 1.652$

STEADY STATE OPERATING MAP (u)

STEADY STATE OPERATING MAP (U)

STEADY STATE OPERATING MAP (U)

Basic Control Loops and Control Components

RN-LH 004-B

STEADY STATE OPERATING MAP (u)

STARTUP TRANSIENT
USING MARK III STRAIGHT INLET PUMP

WATER DATA

STARTUP TRANSIENT
USING MARK III STRAIGHT INLET PUMP

WATER DATA

STARTUP TRANSIENT
USING MARK III STRAIGHT INLET PUMP

WATER DATA

STARTUP TRANSIENT
 USING MARK III STRAIGHT INLET PUMP
 LIQUID HYDROGEN DATA

STARTUP TRANSIENT
USING MARK III STRAIGHT INLET PUMP

LIQUID HYDROGEN DATA
2 PSIA NPSP @ DESIGN

STARTUP TRANSIENT
USING MARK III STRAIGHT INLET PUMP

LIQUID HYDROGEN DATA
2 PSIA NPSP @ DESIGN

STEADY STATE OPERATING MAP (U)

nozzle area 0.1590

MARK III STRAIGHT INLET PUMP PERFORMANCE

TIE ROD CONSTRAINT 1000°R: $P_c = 410$ PSIA

$T_c = 4090^\circ\text{R}$

$Q/N = 0.284$

NPSP = 2 PSIA @ DESIGN

RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - FIXED TPCV POSITION

MARK III STRAIGHT INLET PUMP PERFORMANCE
TIE ROD CONSTRAINT 1000°R: $P_c = 410$ PSIA
 $T_c = 4090^\circ\text{R}$
 $Q/N = 0.284$
NPSP = 2 PSIA @ DESIGN
RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - CLOSED CONTROL LOOP

MARK III STRAIGHT INLET PUMP PERFORMANCE
TIE ROD CONSTRAINT 1000°R: $P_c = 220$ PSIA
 $T_c = 3000^\circ\text{R}$
 $Q/N = 0.258$
NPSP = 2 PSIA @ DESIGN
RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - FIXED TPCV POSITION

MARK III STRAIGHT INLET PUMP PERFORMANCE

TIE ROD CONSTRAINT 1000°R: $P_c = 220$ PSIA
 $T_c = 3000^\circ\text{R}$

$$Q/N = 0.258$$

NPSP = 2 PSIA @ DESIGN

RESPONSE TO STEP DISTURBANCE IN
 FLOW RESISTANCE - CLOSED CONTROL LOOP

MARK III STRAIGHT INLET PUMP PERFORMANCE
TIE ROD CONSTRAINT 1000°R: $P_c = 90$ PSIA
 $T_c = 2000^\circ\text{R}$
 $Q/N = 0.219$
NPSP = 2 PSIA @ DESIGN
RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - FIXED TPCV POSITION

MARK III STRAIGHT INLET PUMP PERFORMANCE

TIE ROD CONSTRAINT 1000°R: $P_c = 90$ PSIA
 $T_c = 2000^\circ\text{R}$

$$Q/N = 0.219$$

NPSP = 2 PSIA @ DESIGN

RESPONSE TO STEP DISTURBANCE IN
 FLOW RESISTANCE - CLOSED CONTROL LOOP

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MARK III STRAIGHT INLET PUMP PERFORMANCE
TIE ROD CONSTRAINT 1200°R: $P_c = 280$ PSIA
 $T_c = 4090^\circ\text{R}$
 $Q/N = 0.238$
NPSP = 2 PSIA @ DESIGN
RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - FIXED TPCV POSITION

MARK III STRAIGHT INLET PUMP PERFORMANCE
TIE ROD CONSTRAINT 1200°R: $P_c = 280$ PSIA
 $T_c = 4090^\circ\text{R}$
 $Q/N \approx 0.238$
NPSP = 2 PSIA @ DESIGN
RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - CLOSED CONTROL LOOP

MARK III STRAIGHT INLET PUMP PERFORMANCE

TIE ROD CONSTRAINT 1200°R: $P_c = 155 \text{ PSIA}$
 $T_c = 3000^\circ\text{R}$

$$Q/N = 0.219$$

NPSP = 2 PSIA @ DESIGN

RESPONSE TO STEP DISTURBANCE IN
 FLOW RESISTANCE - FIXED TPCV POSITION

MARK III STRAIGHT INLET PUMP PERFORMANCE
 TIE ROD CONSTRAINT 1200°R: $P_c = 155$ PSIA
 $T_c = 3000^\circ\text{R}$
 $Q/N = 0.219$
 $\text{NPSP} = 2$ PSIA @ DESIGN
 RESPONSE TO STEP DISTURBANCE IN
 FLOW RESISTANCE - CLOSED CONTROL LOOP

MARK III STRAIGHT INLET PUMP PERFORMANCE
TIE ROD CONSTRAINT 1200°R: $P_c = 50$ PSIA
 $T_c = 2000^\circ\text{R}$
 $Q/N = 0.180$
NPSP = 2 PSIA @ DESIGN
RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - FIXED TPCV POSITION

MARK III STRAIGHT INLET PUMP PERFORMANCE

TIE ROD CONSTRAINT (200°R): $P_c = 50$ PSIA
 $T_c = 2000^\circ\text{R}$

$Q/N = 0.180$

NPSP = 2 PSIA @ DESIGN

RESPONSE TO STEP DISTURBANCE IN
FLOW RESISTANCE - CLOSED CONTROL LOOP