TEST DESCRIPTION
for
EXPERIMENTAL PLAN V
STEAM GENERATOR DEVELOPMENT
TEST PROGRAM

MASTER

23 February 1966

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23 February 1966
NTO-I-0078

TEST DESCRIPTION FOR EXPERIMENTAL PLAN V,
STEAM GENERATOR SYSTEM DEVELOPMENT TEST SERIES

Title of EP: Full Steam Operation of One Steam Generator Module.

Reference: (a) Test Specification - Steam Generator System - Development
Test Program - NES Test Specification No. 005, dated
27 January 1966.

1.0 OBJECTIVES

- 1.1 Evaluate performance and operating characteristics of each steam generator when operated at rated full flow.
- 1.2 Determine propellant pressures, combustion chamber pressure, cooling water pressure, pressure drops and various system pressures.
- 1.3 Confirm weight flow and temperature of propellants, coolant water and steam.
- 1.4 Evaluate first and second-stage ignition and main combustion transients to establish satisfactory operating characteristics.
- 1.5 Assess the Steam Generator System capability for regulating steam temperature with a varying water supply pressure.
- 1.6 Determine allowable low water supply pressure to provide for safe operation.
- 1.7 Qualify the reworked combustion chambers for further testing.

2.0 TEST DESCRIPTION

2.1 Set Up

Steam Generator module S/N 0016, 0017 and 0018 will be setup at steam plenum positions 1, 2 and 3, respectively.

2.2 Test Program

Each generator module will be tested at full flow condition, while the other two generator modules remain at idle flow conditions. All three generator modules will be started and brought to idle operation following a standard start-up sequence procedure. Then the module being evaluated will be brought to full steam operation. The injection water control valve (50-FCV-423) will be adjusted to go to the maximum open position on full steam operation command. The injection water valve to remain in the open position for the first 15 second run. After

steady state full steam operation has been achieved for the 120 and 1000 second full steam run, the injection water control valve (50-FCV-423) will be adjusted to produce a discharge steam temperature of $1300 \pm 100^\circ\text{F}$ as indicated by the average of 50-TT-428, 429, and 430. An orifice in the plenum discharge shall be used for all of these tests to raise chamber pressure to 115 PSIG nominal. Prior to each test, the combustion chamber to injector bolt torque will be checked and retorqued, if necessary, to 390 ft-lb's and the hot gas circuit will be tested to 150 PSIG with GN2.

The tests will be conducted in the order defined below.

Test No.	Full Steam Duration (seconds)	Module Operating at Full Steam	Pressure Water Supply Header (PSIG)	Regulation of Injection Water During Test?	Steam Temp Regulation Goal ($^\circ\text{F}$)	C3H8 Supply Temp. ($^\circ\text{F}$)	C3H8 Flow Rate lb/sec	LOX Supply Temp. ($^\circ\text{F}$)	LOX Flow Rate lb/sec
1.	15	S/N 0016	Normal	Wide Open	N.A.	**	7.7	-282 ± 5	18.5
2.*	120	S/N 0016	175	Yes	1300 ± 100	**	"	"	"
3.	1000	S/N 0016	Normal	Yes	1300 ± 100	**	"	"	"
4.	15	S/N 0017	Normal	Wide Open	N.A.	**	7.7	-282 ± 5	18.5
5*	120	S/N 0017	175	Yes	1300 ± 100	**	"	"	"
6.	1000	S/N 0017	Normal	Yes	1300 ± 100	**	"	"	"
7.	15	S/N 0018	Normal	Wide Open	N.A.	**	7.7	282 ± 5	18.5
8.*	120	S/N 0018	175	Yes	1300 ± 100	**	"	"	"
9.	1000	S/N 0018	Normal	Yes	1300 ± 100	**	"	"	"

* Module operating at full steam will be automatically shutdown after 120 seconds by commanding the LO₂ Main Stage Propellant Valve closed. As soon after shutdown as possible the propane concentration in the plenum and stack shall be determined. For the 120 second runs, a water supply pressure of 175 PSIG will be maintained in the header by manually pre-adjusting 50-GLV-1781 while flowing the water system cooling circuits.

** This value will be supplied at a later date in a supplement to this test specification.

2.3 Inspection

On conclusion of the test program, the following inspections will be performed:

2.3.1 Injector

Dye penetrant inspection for cracks in injector faces on other damage. Document inspection by close-up photographs. LO₂ clean injectors prior to reassembly.

2.3.2 Combustion Chamber

2.3.2.1 Expansion Joints

Dye penetrant inspection.

2.3.2.2 Chamber Liner

Visual inspection, check for damage and hot spots.

2.3.3 Plenum

Visually inspect interior for erosion and overheating.

2.4 Test Schedule

One full steam test will be accomplished on each run day with three run days scheduled each week.

The tests will be conducted in accordance with the Control Room Procedure which will be available on R-1 Day. The access list will be prepared on R-1 Day. Area control will be initiated at 1700 hours on R-Day.

Operations will commence at 1500 hours on R-Day with the setup of instrumentation and the exercising of valves. After area control (ETS-1 Area Control and Safety Standards for Steam Generator Testing, NTO-SOP-0068) is imposed, the LO₂ system bleed-in will be initiated, followed by bleed-in of the propane system. The propellant tanks will be pressurized and the test will be performed.

After completion of the test, the system will be secured to allow re-entry for visual examination of the steam generator. Strip chart and oscillograph records will be examined and preliminary calculations will be performed.

The planned run schedule is as follows:

14 March 1966	15 Sec. Full Steam	S.G. No. 1
15 March 1966	120 Sec. Full Steam	S.G. No. 1
17 March 1966	1000 Sec. Full Steam	S.G. No. 1
21 March 1966	15 Sec. Full Steam	S.G. No. 2
22 March 1966	120 Sec. Full Steam	S.G. No. 2
24 March 1966	1000 Sec. Full Steam	S.G. No. 2
28 March 1966	15 Sec. Full Steam	S.G. No. 3
29 March 1966	120 Sec. Full Steam	S.G. No. 3
31 March 1966	1000 Sec. Full Steam	S.G. No. 3

Following these tests, one week is scheduled for the inspection defined in paragraph 2.3.

3.0 SPECIAL SYSTEM EVALUATION REQUIREMENTS

3.1 Bolt Orifice Evaluation

All bolt orifices (P/N 940030-1) will be removed from the generator before and after each 1000 second full steam run and evaluated for erosion, and the following measurements recorded:

3.1.1 Diameter at area of maximum erosion (minimum diameter).

3.1.2 Distance from end of bolt orifice to centerline of maximum erosion.

Detailed photographs of all eroded areas, showing top and side view, will be taken. Bolt orifice threads shall be cleaned and a suitable lubricant applied prior to re-installation.

4.0 PREMATURE TEST TERMINATION CRITERIA

The following are specific conditions which warrant shutdown of the steam generator. However, should any erratic operation occur, the test shall be terminated.

4.1 An electron beam point on an oscilloscope face, representing instantaneous propane conditions (Pressure ① vs Temperature ②) shall be compared visually to a vapor pressure curve ③ affixed to the face of the oscilloscope. If the point on the scope moves below the curve (indicating propane flashing) execute immediate shutdown. This applies only to the specially instrumented injectors.

① 50-PT-704

② 50-TT-703

③ Curve "A" of Appendix I

4.2 Should the propane flow rate show a decrease to 90% of nominal flow rate after steady state conditions have been achieved, execute immediate shutdown.

- 4.3 Should the steam temperature as measured by 50-TT-435, 436 and 437 exceed 1600 °F, execute immediate shutdown.
- 4.4 Should coolant water jacket outlet temperature (50-TT-434) and/or plenum coolant water outlet temperature (50-TT-431) approach boiling, execute immediate shutdown.
- 4.5 Should the main stage chamber pressure exceed 160 PSIG, execute immediate shutdown.

5.0 SAFETY REQUIREMENTS

- 5.1 The safety requirements specified in NTO-SOP-0068.
- 5.2 Following each test, gas samples shall be taken from the steam plenum with a combustible gas analyzer to verify that the propane valves are properly seated and not leaking.

6.0 QUALITY CONTROL REQUIREMENTS

- 6.1 Prior to start of full steam operation, it shall be verified that all repairs and modifications to the steam generator system have been properly documented.
- 6.2 Prior to start of full steam operation, it shall be verified that all test equipment has been properly calibrated and documented.

7.0 SUPPORT REQUIREMENTS

7.1 Major Test Participants		Alternates
Facility Manager	B. Bernstein	D. D. Vander Meer
Test Director	H. Henze	V. R. Davis
		N. E. Erickson
		T. A. Keasling
		J. F. Christenson
		B. A. Bernstein
Assistant Facility Engineer, Left	E. B. Graham	T. A. Keasling
	J. A. Gaccione	E. M. Shultis
Health & Safety	F. M. Cox	R. E. Benshoof
Security	A. B. Bagwell	J. S. Holt
Support	A. R. Marshall	W. J. Reibel
Advisor	NES Project Representative	

7.1 Major Test Participants (Cont'd)

Quality Control	C. A. Thomas	D. J. McCroskey
Instrumentation	D. E. Bridenstine	R. G. Cooper
Facility Control	A. P. Vogt	D. S. Beesley
TV & Communications	R. C. Chavez	A. P. Vogt

7.2 Facility Conditions

7.2.1 GN₂ System

This system will be charged to a normal operating pressure with a maximum pressure of 2500 PSIG, and a minimum pressure of 1500 PSIG.

7.2.2 Process Water System

The level in the process water tank shall not be lower than 10 feet.

7.2.3 LO₂ System

The liquid level in the tank will be maintained consistent with economical scheduling; however, the tank level shall not be permitted to drop below 10,000 gallons. The dewar shall be pressurized to provide a flow rate of 18.5 lb/sec during steady state operation. The tank pressure will be set in accordance with Appendix 2a, 2b or 2c.

7.2.4 Propane System

The tank level shall not be permitted to drop below 7,000 gallons. The tank shall be pressurized to provide a flow rate of 7.7 lb/sec during steady state operation.

7.3 Instrumentation and Data Acquisition Requirements

7.3.1 Data requirements are as shown in Appendix 3. Refer to Appendix 4 for location and nomenclature of instrumentation.

7.3.2 The oscillograph chart speed shall be operated at approximately 10 in/sec during transient condition and reduced to approximately 1 in/sec during steady state operation for all tests in excess of 30 seconds at full steam. The test title and identification, including date, shall appear on each record. All parameters shall be identified on the record.

7.3.3 Photographic coverage for selected tests will be provided to show:

- a) Exhaust Stack (infrared)
- b) Steam Generator Enclosure (color)

The camera will run at 24 FPS and use 16mm film. Locations of cameras to be mutually agreed upon between Test Director and Photographer.

- 7.3.4 Television coverage will be used for test observation and for surveillance of the facility from safety consideration. The following cameras will be used, although all existing cameras (14) will be operational and capable of being substituted.

<u>Monitor No.</u>	<u>Camera Position No.</u>	<u>Location</u>	<u>Primary Observation</u>
1	1	North of Ditch	TS, Pad, Ditch
2	5	North End of Shadow Wall	S.G. Enclosure
3	20	Tripod North of LO ₂ Dewar	Pipe Chase Toward TS
4	6	Atop LH ₂ Dewar	Test Stand
5	7	Atop Fill Station	LO ₂ Dewar and TS
6	13	Northeast of Steam Generator	S.G. Enclosure
7	15	Tripod Southwest of Propane Tank	Propane Tank
8	3	West of Ditch	Flare Stack

Auxiliary illumination will be provided by search lights trained on the test stand structure and steam pipe.

7.4 Area Control

Area control will be in effect from 1700 hours on R-Day and remain in effect until securing operations have been completed as announced by the Test Director.

7.5 Pan American Airways

7.5.1 Operating Technicians

The crew normally assigned to the Steam Generator Operation shall be available. Overtime may be necessary in the event of unforeseen circumstances.

7.5.2 Photographic Services

Camera equipment and photographers are required to provide coverage from two locations. Overtime operation may be necessary.

7.6 EG&G

EG&G support is required to process the oscillograph records produced during the test. These records will be delivered to EG&G as available by NTO personnel.

8.0 REPORTS

- 8.1 A "Quick Look" data report will be sent to project via TWX the day after a test. See Appendix 5 for format.

Steam Generator
Minimum Allowable Injector Fuel Pressure
vs
Fuel Temperature

PfJ-1 or 3, INJECTOR FUEL PRESSURE, PSIG

300

200

100

0

0 20 40 60 80 100 120 140

TfJ4-1 or -3, INJECTOR FUEL TEMPERATURE °F

CURVE "A"

Propane

LO₂ VENTURI INLET
PRESSURE vs. LO₂ FLOW RATE
GENERATOR S/N 17
(MODULE #2)

POV3-2, MAIN STAGE LO₂ VENTURI INLET PRESSURE, PSIG

LO₂ VENTURI INLET
PRESSURE vs LO₂ FLOW RATE
GENERATOR S/N 18
(MODULE #3)

POV3-3 MAIN STAGE LO₂ VENTURI INLET PRESSURE, PSIG

ENGINE TEST STAND NO. 1
NRDS, NEVADA
NERVA TEST OPERATIONS

ENGINE NO. _____
TEST FACILITY Steam Generator System
SERIES & TEST NO. Experimental Plan V
W.O. NO. _____

PAGE 1 OF 3
DATE OF REQUEST _____
TEST ENGR. H. Henze
INSTR. ENGR. R. Cooper

INSTRUMENTATION REQUEST

		RECORDING METHOD													REMARKS		
FUNCTION	RANGE	OSC.			STRIP CHART						CSCR "A"	Meter on TD Console	Meter on ATD Console	DDS	Oscilloscope	EVENTS-Rec.	
		R1	R2	R3	A	B	C	D	E	F							
PfJ1-1	0-500 psig	X							1					X			50-PT-407-1
PfV2-1	0-500 psig	X							2					X			50-PT-408-1
PfJ3-1	0-500 psig	X												X			50-PT-409-1
PfV3-1	0-500 psig	X												X			50-FT-405-1
PfV3-1	0-200 psid	X			4									X			50-PT-571-1
PoV2-1	0-500 psig	X												X			50-PT-414-1
PoJ3-1	0-500 psig	X												X			50-PT-415-1
PoV3-1	0-500 psig	X			3									X			50-FT-409-1
PwC03-1	0-200 psig	X												X			50-PT-410-1
PwJ-1	0-200 psig	X												X			50-PT-411-1
PwV-1	0-250 psid	X			5									X			50-FT-406-1
Pc1-1	0-250 psig	X												X			50-PT-416-1
Pc2-1	0-250 psig	X												X			50-PT-417-1
PcU3-1	0-200 psig	X			1									X			50-PT-709-1
PcL3-1	0-200 psig	X			2								6	X			50-PT-438-1
Tc1-1	32-2300°F	X												X			50-TT-435-1
Tc2-1	32-2300°F	X												X			50-TT-436-1
Tc3-1	32-2300°F	X												X			50-TT-437-1
TcAV-1	32-2300°F	X							1					X			
TwC03-1	0-150°F	X				6								X			50-TT-434-1
LwCV-1	0-3"	X												X			50-FCV-423-1
IwCV-1	0-3"	X												X			50-FCV-423-1
TfJ3-1	32-251°F	X												X			50-TE-703-1
TfJ4-1	32-251°F	X			7							6		X	X		50-TE-704-1
PfJ-1	0-300 psig	X			8							1		X	X		50-PT-703-1
PoJ3-1	0-200 psid	X												X			50-PT-706-1
PfJ3-1	0-200 psid	X			6									X			50-PT-705-1
PoT	0-500 psig	X						1						X			50-PT-49
PoM	0-500 psig	X						2				5		X			50-PT-421
ToM	-390°F to -170°F	X						3				10		X			50-TT-479
ToB-1	-390°F to -170°F												9	X			50-TE-707-1
PfJ1-2	0-500 psig		X						3					X			50-PT-407-2
PfV2-2	0-500 psig		X						4					X			50-PT-408-2
PwV0-1	0-250 psig	X												X			50-PT-701-1
PfJ3-2	0-500 psig		X											X			50-PT-409-2
PfV3-2	0-500 psig		X											X			50-FT-405-2
PfV3-2	0-200 psid		X		4									X			50-PT-571-2
PoV2-2	0-500 psig		X											X			50-PT-414-2
PoJ3-2	0-500 psig	X												X			50-PT-415-2

SERIES & TEST NO. _____

PAGE 2 OF 3

		RECORDING METHOD												REMARKS			
FUNCTION	RANGE	OSC.			STRIP CHART						CSCR "A"	Meter on TD Console	Meter on ATD Console	DDS	Oscilloscope	EVENTS-Rec.	
		R1	R2	R3	A	B	C	D	E	F							
PoV3-2	0-500 psig		X			3								X			50-FT-409-2
PwC03-2	0-200 psig		X											X			50-PT-410-2
PwJ-2	0-200 psig		X											X			50-PT-411-2
PwV-2	0-250 psid		X			5								X			50-FT-406-2
Pc1-2	0-250 psig		X											X			50-PT-416-2
Pc2-2	0-250 psig		X											X			50-PT-417-2
PcU3-2	0-200 psig		X			1								X			50-PT-709-2
PcL3-2	0-200 psig		X			2							7	X			50-PT-438-2
Tc1-2	32-2300°F		X											X			50-TT-435-2
Tc2-2	32-2300°F		X											X			50-TT-436-2
Tc3-2	32-2300°F		X											X			50-TT-437-2
TcAV-2	32-2300°F		X							2				X			
TwC03-2	0-150°F		X			7								X			50-TT-434-2
LwCV-2	0-3"		X											X			50-FCV-423-2
IwCV-2	0-3"		X											X			50-FCV-423-2
PsP1	0-250 psig		X						7					X			50-PT-425
PsP2	0-250 psig		X									3		X			50-PT-426
TsP1	32-2300°F		X								1			X			50-TE-504
TsP2	32-2300°F		X								2			X			50-TE-505
TsP3	32-2300°F		X								3			X			50-TE-506
TsPAV	32-2300°F		X							4				X			
TsE1	32-2300°F		X								4			X			50-TT-428
TsE2	32-2300°F		X								5			X			50-TT-429
TsE3	32-2300°F		X								6			X			50-TT-430
TsEAV	32-2300°F		X							5		8		X			
TwPO	0-150°F		X					8						X			50-TT-431
PwH	0-300 psig		X											X			50-PT-168
PwM	0-250 psig		X						8					X			50-PT-427
PfJ1-3	0-500 psig			X					5					X			50-PT-407-3
PfV2-3	0-500 psig			X					6					X			50-PT-408-3
PfJ3-3	0-500 psig			X										X			50-PT-409-3
PfV3-3	0-500 psig			X										X			50-FT-405-3
ΔPfV3-3	0-200 psid			X			4							X			50-PT-571-3
PoV2-3	0-500 psig			X										X			50-PT-414-3
PoJ3-3	0-500 psig			X										X			50-PT-415-3
PoV3-3	0-500 psig			X			3							X			50-FT-409-3
PwC03-3	0-200 psig		X											X			50-PT-410-3
PwJ-3	0-200 psig			X										X			50-PT-411-3
ΔPwV-3	0-250 psid			X			5							X			50-FT-406-3
Pc1-3	0-250 psig			X										X			50-PT-416-3
Pc2-3	0-250 psig			X										X			50-PT-417-3
PcU3-3	0-200 psig			X			1							X			50-PT-709-3
PcL3-3	0-200 psig			X			2					8		X			50-PT-438-3
Tc1-3	32-2300°F			X										X			50-TT-435-3

		RECORDING METHOD													REMARKS		
FUNCTION	RANGE	OSC.			STRIP CHART						CSCR "A"	Meter on TD Console	Meter on ATD Console	DDS	Oscilloscope	EVENTS-Rec.	
		R1	R2	R3	A	B	C	D	E	F							
Tc2-3	32-2300°F			X										X			50-TT-436-3
Tc3-3	32-2300°F			X										X			50-TT-437-3
TcAV-3	32-2300°F			X							3			X			
TWC03-3	0-150°F			X		8								X			50-TT-434-3
LwCV-3	0-3"			X										X			50-FCV-423-3
IwCV-3	0-3"			X										X			50-FCV-423-3
TfJ3-3	32-251°F			X										X			50-TE-703-3
TfJ4-3	32-251			X			7					7		X	X		50-TE-704-3
PfJ-3	0-300 psig			X			8					2		X	X		50-PT-703-3
POJ3-3	0-200 psid			X										X			50-PT-706-3
PfJ3-3	0-200 psid			X			6							X			50-PT-705-3
PfT	0-500 psig			X				4						X			34-PT-118
PfM	0-500 psig			X				5				4		X			50-PT-420
TfT	0-150°F			X				7						X			34-TT-483
TfM	0-150°F			X				6				9		X			50-TT-478
Wf	0-500 cps.			X						6				X			50-FT-701
Start)	)																
1st stage signal)	)																
2nd stage signal)	)	X	X	X										X			S.G.#1
Main LO2 valve signal)	)																
Main fuel valve signal)	)																
Start)	)																
1st stage signal)	)																
2nd stage signal)	)	X	X	X										X			S.G.#2
Main LO2 valve signal)	)																
Main fuel valve signal)	)																
Start)	)																
1st stage signal)	)																
2nd stage signal)	)	X	X	X										X			S.G.#3
Main LO2 valve signal)	)																
Main fuel valve signal)	)																

STEAM GENERATOR QUICK LOOK DATA REPORT

TEST: _____

DATE: _____

DESCRIPTION: _____

TEST DATA

Run Duration (Full Steam):	_____ sec.	Data Time:	_____ sec.
PoM, LO ₂ Manifold Pressure (50-PT-421)	_____		psig
ToM, LO ₂ Manifold Temperature (55-TT-479)	_____		°F
PfT, Fuel Tank Pressure (34-PT-118)	_____		psig
TfT, Fuel Tank Temperature (34-TT-483)	_____		°F
PfM, Pressure Manifold Fuel (50-PT-420)	_____		psig
TfM, Fuel Manifold Temperature (50-TT-478)	_____		°F
PwM, Water Inlet Manifold Pressure (50-PT-427)	_____		psig
TwPO, Plenum Coolant Water Outlet Temperature (50-TT-431)	_____		°F
TwCO3-__, Chamber Coolant Water Outlet Temperature (50-TT-434)	_____		°F
PfJ- __, Injector Fuel Pressure (50-PT-703)	_____		psig
△ PfJ3-__, Injector Fuel Pressure Drop (50-PT-705)	_____		psig
TfJ4- __, Injector Fuel Temperature (50-TE-704)	_____		°F
PcU3- __, Chamber Pressure (50-PT-709)	_____		psig
PcL3- __, Chamber Pressure (50-PT-438)	_____		psig
TcAV- __, Chamber Temperature (av. of 50-TT-435, 436, 437)	_____		°F
PsPl, Steam Plenum Pressure (50-PT-425)	_____		psig
TsPAV, Plenum Steam Temperature (av. of 50-TE-504, 505, 506)	_____		°F
TsEAV, Steam Temperature (av. of 50-TT-428, 429, 430)	_____		°F
° Wt, Fuel Flow Rate: Desired _____	lb/sec	Actual _____	lb/sec
° Wo, LO ₂ Flow Rate: Desired _____	lb/sec	Actual _____	lb/sec
° Ww, Injection Water Flow Rate		_____	lb/sec