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FAILURE MODE AND EFFECT ANALYSIS ON JTF17 FUEL AND CONTROL SYSTEM. APPENDIX A.

PRATT AND WHITNEY AIRCRAFT WEST PALM BEACH FL

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APPENDIX A

FAILURE MODE AND EFFECT ANALYSIS
ON
JTF17 FUEL AND CONTROL SYSTEM

Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION
FLORIDA RESEARCH AND DEVELOPMENT CENTER

Printed in the United States of America

CONTENTS

INTRODUCTION

This preliminary Failure Modes and Effects Analysis report is the study made of a representative proposed JTF17 Fuel and Control System. This study was made concurrent with design studies of the fuel and control system and concurrent with review of the proposals submitted by various vendors for a particular component. By necessity this study represents a finite level of the continuing component designs and one proposal for a particular vendor component. Component vendor selection for inclusion in this study was arbitrary and is not intended to reflect final component vendor selection. This study has revealed some areas that did not conform to the failsafe requirements established for the system. These areas have been reviewed and design changes initiated to minimize the probability of malfunctions and reduce the seriousness of the consequences of the malfunction. Where possible, such corrective changes are indicated in this study, but some of the changes were not resolved in time for incorporation. Follow-up is done on a continuing basis and future revisions to the study will be made at six-month intervals beginning in July 1967. The first such revision will reflect a more complete design level, the selection of component vendors, and corrective changes required as the result of this study. In addition, the first revision will include hazard classification and design philosophy to preclude failure and to reduce hazard.

This report is divided into two sections. Section I presents the effects of component sense or signal failures on engine operation. A fold-out block diagram is contained at the beginning of this section that can be exposed while reading both sections of the report.

Section II presents the effects of detail part failures within each component. A description, analysis, and fold-out schematics are presented for each component with the schematics arranged to follow the analysis of the applicable component so that by prior exposure it may be viewed while reading the component material. The detail part Failure Mode Index Number assigned to each component part is identified both in the analysis and schematic for each component.

Each failure considered was examined for effect on the fuel and control system, method of detection, effect on the engine, effect on the aircraft, and crew action required. For purposes of this study, failures at three flight conditions were considered:

1. Committed sea level takeoff (0 to 6000 ft) with maximum augmentation on a 100°F day.
2. Cruise at design flight conditions.
3. Lending at reduced nonaugmented power on a 100°F day.

Where possible the failure effect on the engine is shown at each of the above flight conditions as the maximum available thrust after the failure, F_n, expressed as a percent of the normal maximum augmented thrust, F_{nma}, at the same condition.

Where applicable, problems after failure with respect to climb, descent, landing wave-off, landing reverser actuation, and shutdown of the engine after landing are also presented.

This study assumed at least the following engine instrumentation is available to the aircraft crew in order to detect a failure:

- High compressor rotor speed (N_2)
- Turbine discharge total temperature (T_{t7})
- Engine pressure ratio (EPR)
- Gas generator fuel flow
- Duct heater fuel flow
- Engine oil temperature
- Duct nozzle position indicator
- Reverser-suppressor position

The majority of failures can be detected in flight by the aircraft crew with the above instrumentation. Some of the failures are detectable only on engine shutdown or during routine ground inspection and maintenance, and such methods of detection are included in this study.

The following abbreviations and symbols are used in this report:

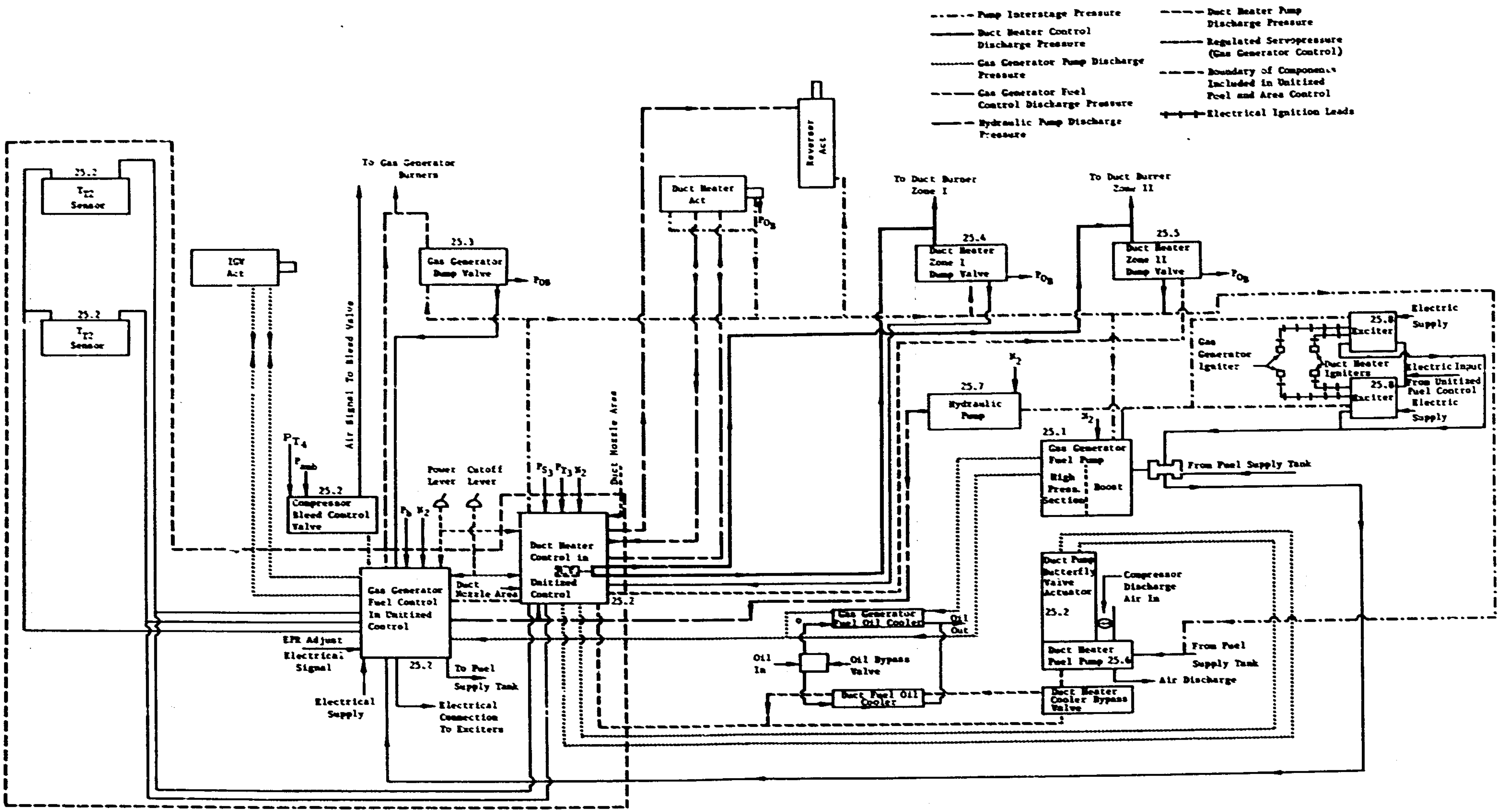
SLTO	Sea level takeoff
F_n	Thrust
F_{nma}	Normal maximum augmented thrust
PLA	Power lever angle
SOL	Shut-off lever
P_{t4}	Compressor discharge total air pressure
P_{t3}	Duct heater total pressure
P_{s3}	Duct heater static pressure
T_{t2}	Compressor inlet air total temperature
T_{t7}	Turbine discharge total temperature
N_1	Low compressor rotor speed
N_2	High compressor rotor speed
EPR	Engine pressure ratio
Failure Effect on Aircraft Classifications	
PER	Premature engine removal
IFS	In-flight shutdown
AF	Inability to obtain a selected level of augmented thrust
DD	Delay in dispatch or departure
CR	Repair or replace component without engine removal

SECTION I
EFFECTS OF COMPONENT SENSE OR SIGNAL FAILURES ON ENGINE OPERATION

This section presents the study of the effects of component sense or signal failures on engine operation. While experience with other Pratt & Whitney Aircraft engines has shown the majority of such failures will not occur in service, the probability of each failure is not negligible and may be caused by sense or signal carrying line failure or contamination blockage, shearing of drive gear sections due to overloads, fracture or seizing of rigging cable systems, fuel supply mismanagement or boost pump failure, or electrical systems opens or shorts. The use of a Failure Mode Index number was not felt to be applicable for failures presented in this section, therefore a simple sequence numbering system was used.

The failure of a fuel carrying signal line could be the result of a significant external fuel leak of such line. Fuel leakage from such failures can be stopped by closing the aircraft valve that supplies fuel to the engine. When this valve is closed, fuel cooling of engine oil will not be possible. Each signal failure which could be the result of a fuel leak is marked by an asterisk.

JTF17 FUEL AND CONTROL SYSTEM SCHEMATIC



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Sheet 1

JTF17 FAILURE MODE & EFFECT ANALYSIS

No.___ of___

Component Sense or Signal Failures

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
1. Speed Drive To Gas Generator Fuel Pump	Provide rotational energy to the gas generator fuel pump.	Drive Failure	SLTO: Complete loss of gas generator fuel flow and resultant duct heater shutoff	Gas generator and duct heater flame out. No gas generator fuel flow indication if relight attempted.	Gas generator and duct heater flame out.	IFS	In-flight engine shutdown. Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Complete loss of gas generator fuel flow and resultant duct heater shutoff. Insufficient fuel flow to engine oil coolers	Same as SLTO	Gas generator and duct heater flame out. Engine oil temperature will increase and exceed limits without crew action.	Same as SLTO	In-flight engine shut down. Adjust F_N level on unaffected engines to obtain desired aircraft conditions. Monitor engine oil temperature. If necessary to maintain oil temperature limit, reduce speed to subsonic.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
2. Engine Fuel Supply Pressure	To supply fuel under a positive head to the engine fuel pumps.	Reduced Inlet Pressure (Boost Pumps Off)	SLTO: The pumps can operate satisfactorily with an inlet pressure of 5 psi above the absolute vapor pressure of the fuel or at a vapor-liquid ratio of 0.45.	None	Not Affected	Not Affected	None
			If inlet pressure is below 5 psi above the absolute vapor pressure of the fuel or at vapor-liquid ratio greater than 0.45, the pumps cavitate and cease to pump continuously.	Engine performance deterioration with eventual gas generator and duct heater flame out.	The interrupted fuel flow will result in engine performance deterioration with eventual gas generator and duct heater flame out.	IFS	Reduce SOL to off position and attempt relight.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO. A reduction in altitude to increase fuel tank pressure may be beneficial.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
* 3. Engine Fuel Supply	To supply fuel to the engine	Loss of fuel supply to engine	SLTO: Complete loss of gas generator fuel flow and resultant duct heater shut off.	Gas generator and duct heater flame out. No gas generator fuel flow indication if relight attempted.	Gas generator and duct heater flame out.	IFS	In flight engine shutdown. If fuel supply cannot be restored, adjust F_N level on unaffected engines to obtain desired aircraft conditions.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

No.___ of_____

Component Sense or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
			Cruise: Complete loss of gas generator fuel flow and resultant duct heater shutoff. Insufficient fuel flow to engine oil coolers.	Same as SLTO	Gas Generator and duct heater flame out. Engine oil temperature will increase and may exceed limits	Same as SLTO	Inflight engine shutdown. If fuel supply cannot be restored and engine restarted, adjust F_N level on unaffected engines to obtain desired aircraft conditions. Monitor engine oil temperature. If necessary to maintain engine oil temperature limit, reduce aircraft speed to subsonic conditions.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
4. Compressor Bleed Air Supply to Duct Heater Fuel Pump	Energy Supply to Drive Duct Heater Fuel Pump	Complete Loss of Pump Air Supply	SLTO: Loss of duct heater fuel flow if on or cannot be initiated if off.	Loss of duct heater fuel flow if on or cannot be initiated if off.	Duct heater will flame out if on or cannot be initiated if off. F_N = 60% F_NMA	AF	Reduce to and/or maintain non augmented PLA range. Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except F_N = 20% F_NMA. In addition oil temperature will increase and may eventually exceed limits due to loss of duct heater oil cooler fuel flow.	Same as SLTO Also may have IFS	Reduce to and maintain non augmented PLA range. Adjust F_N level on unaffected engines to obtain desired aircraft conditions. Monitor engine oil temperature. If necessary to maintain engine oil temperature limit, reduce aircraft speed to subsonic conditions.
			Landing: Not Affected Duct heater fuel flow not available.	Not Affected	Not Affected If maximum F_N desired, same as SLTO	Same as SLTO	None If maximum F_N desired, Same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
5 Speed Drive to Hydraulic Pump	Provides Rotational Energy to the Hydraulic Pump	Drive Failure	SLTO: Will cause pumping failure resulting in complete loss of hydraulic pressure. Duct nozzle goes to open position	Duct nozzle to open position.	N_1 higher than normal F_N = 90% F_NMA	AF	Adjust F_N Level on unaffected engines to obtain desired aircraft conditions
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except F_N = 85% MA	Same as SLTO	Same as SLTO
			Landing: Same as SLTO. In addition, reverser-suppressor actuation not available.	Same as SLTO. In addition, reverser-suppressor cannot be actuated.	Some reduction in F_N. N_1 higher than normal. Reverse F_N not available. If maximum F_N desired, same as SLTO	Same as SLTO	Adjust PLA to obtain desired landing F_N. If reverse F_N desired, retard PLA to idle and adjust F_N level on unaffected engines to obtain desired aircraft conditions. If maximum F_N desired, same as SLTO
6 Speed Drive to Unitized Control	Supplies a rotational high rotor speed signal to the gas generator speed sensor to schedule gas generator fuel flow/burner pressure as a function of speed.	Loss of Speed Sense	SLTO: Gas generator fuel flow ratio scheduled by the failsafe plateau with translation to plateau generally in decreasing ratio direction. Bleeds and inlet guide vanes scheduled by failsafe plateaus. Lose duct heater fuel flow if on or cannot initiate if off.	N_2, T_{T2} and EPR lower than normal. Duct heater shuts off if on or cannot be initiated if off.	F_N = 35% F_NMA	AF	Decrease to and/or maintain non-augmented PLA range. Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_N = 5% F_NMA	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
7. P_B Sense to Unitized Control	Primary combustor pressure sense which biases fuel flow to provide the proper fuel/air ratio to the gas generator and duct heater	a. Partial loss of P_B sense (slight leak)	SLTO: Reduction in gas generator and duct heater fuel flow as a function of lower effective P_B. Reduction dependent on amount of P_B sense loss.	N_2, T_{T2} and EPR lower than normal. Gas generator and duct heater fuel flow lower than normal	N_2, T_{T2} and EPR lower than normal. Loss of thrust. Reduction dependent on amount of P_B sense loss.	If P_B sense loss is significant, AF.	Adjustment of manual remote EPR control will compensate for P_B sense loss.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
7. P_b Sense to Unitized Control (Continued)		b. Complete loss of P_b sense	SLTO: Gas generator and duct heater fuel flow decrease to minimum flow value.	Gas generator and duct heater flameout. Gas generator minimum fuel flow if relight attempted.	Gas generator and duct heater flameout.	IFS	In-flight engine shutdown. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	N_2, T_{t7} and EPR lower than normal. Gas generator and duct heater fuel flows lower than normal.	F_n = -10% F_{nma}.	AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
					On descent will eventually have gas generator flameout.	IFS	In-flight shutdown. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
8. Engine Power Lever	Aircraft crew command input to control system.	Loss of power lever input to control system.	SLTO: Control system will remain at setting existing at time of failure. T_{t2} bias of schedules will continue to function.	No control of engine power setting.	Engine power remains at setting existing at time of failure. T_{t2} bias of power setting continues to function.	Not affected at conditions existing at time of failure. If additional power desired, AF.	None at conditions existing at time of failure. If power change desired, adjust F_n level on unaffected engines to obtain desired aircraft conditions. Engine can be shut down with SOL.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO. In addition, reversor-suppressor actuation not available.	Same as SLTO. In addition, reverser-suppressor cannot be actuated.	Same as SLTO. In addition, reverse thrust not available.	Same as SLTO	Same as SLTO
9. Engine Shut-off Lever	Aircraft crew command input to select engine on or off conditions.	Loss of shut-off lever input to control system.	SLTO: Control system operation not affected. Will require use of aircraft fuel valve to shut down engine.	Cannot shut down engine with SOL.	Engine operation not affected. Cannot shut down engine with SOL.	Not affected	None. Use aircraft fuel valve when engine shut down desired.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	Same as SLTO
10. Manual Remote EPR Control	Provision for aircraft crew adjustment of EPR by gas generator fuel adjustment.	a. Failure to full decrease authority.	SLTO: Gas generator and duct heater fuel flow lower than normal. Lose remote EPR adjustment capability.	N_2, gas generator fuel flow, duct heater fuel flow, EPR, and T_{t7}, all lower than normal.	F_n = 75% F_{nma}.	AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 85% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	Not affected	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

No.____of____

(Input Sensor or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
10. Manual Remote EPR Control (Continued)		b. Failure to full increase authority.	SLTO: Gas generator and duct heater fuel flow higher than normal. Lose remote EPR adjustment capability.	N_2, gas generator fuel flow, duct heater fuel flow, EPR, and T_{t7} all higher than normal. Engine may surge.	N_1, N_2, gas generator fuel flow, duct heater fuel flow, EPR, and T_{t7} all higher than normal. Engine may surge. If engine surges: F_n = 65% F_{nma}.	After takeoff, AF except for emergency conditions. If engine surges, AF.	If engine does not surge, none until takeoff is completed. If engine surges or as soon as possible reduce PLA to nonaugmented range and modulated below T_{t7} limit level. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except no surge. Augmentation must be shut off to maintain T_{t7} limit. With augmentation off F_n = 70% F_{nma}.	To maintain T_{t7} limit, AF.	Reduce PLA to nonaugmented range and modulate below T_{t7} limit level. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Landing: Not affected	Not affected	Not affected	Not affected	None. Do not attempt augmentation except in an emergency situation.
		c. Loss of power supply.	SLTO: No immediate effect. Lose remote EPR adjustment capability.	Lose remote EPR adjustment capability.	No immediate effect. Lose remote EPR adjustment capability.	No immediate effect. If EPR exceeds limit, AF.	None. If EPR exceeds limit, reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired, same as SLTO.	Same as SLTO	Not applicable. If maximum F_n desired, same as SLTO.	Not applicable	None. If maximum F_n desired, same as SLTO.
11. Manual Remote Duct Heater Fuel Flow Adjustment	Provision for aircraft crew adjustment of duct heater fuel flow.	a. Failure to full decrease authority	SLTO: Duct heater fuel flow lower than normal. Lose remote duct heater fuel flow adjustment capability.	Duct heater fuel flow and duct nozzle area less than normal. Lose remote duct heater fuel flow adjustment capability.	F_n = 95% F_{nma}.	AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions
			Cruise: Same as SLTO	Same as SLTO	F_n 90% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired, same as SLTO.	Same as SLTO	Not applicable. If maximum F_n desired, same as SLTO.	Not applicable	None. If maximum F_n desired, same as SLTO.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
11. Manual Remote Duct Heater Fuel Flow Adjustment (Continued)		b. Failure to full increase authority.	SLTO: Duct heater fuel flow greater than normal. Lose remote duct heater fuel flow adjustment capability.	Duct heater fuel flow and duct nozzle area larger than normal. Lose remote duct heater fuel flow adjustment capability.	Duct heater fuel flow higher than normal.	None	Reduce PLA on affected engines
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 105% F_{nnom}	None	Same as SLTO
			Landing: Not applicable. If maximum F_n desired, same as SLTO.	Same as SLTO	Not applicable. If maximum F_n desired, same as SLTO.	Not applicable	None. If maximum F_n desired, same as SLTO.
		c. Loss of power supply.	SLTO: No immediate effect. Lose remote duct heater fuel flow adjustment capability.	Lose remote duct heater fuel flow adjustment capability.	No immediate effect. Lose remote duct heater fuel flow capability.	No immediate effect.	None. If duct heater fuel flow exceeds desired level, reduce PLA
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	No immediate effect.	Same as SLTO
			Landing: Not applicable. If maximum F_n desired, same as SLTO.	Same as SLTO	Not applicable. If maximum F_n desired, same as SLTO.	Not applicable	None. If maximum F_n desired, same as SLTO
12. Manual Remote Total Airflow Adjustment	Provision for aircraft crew adjustment of engine total airflow during augmentation.	a. Failure to full decrease authority.	SLTO: Not affected. This adjustment has no authority at SLTO.	Not affected	Not affected	Not affected	None
			During climb above approximately 240°F T_{t2}, nozzle area less than nominal.	Duct nozzle area less than nominal. Lose remote duct nozzle adjustment capability.	Total engine airflow less than nominal.	Essentially not affected.	None
			Cruise: Duct area less than nominal.	Duct nozzle area less than nominal. Lose remote duct nozzle adjustment capability.	Total engine airflow less than nominal. F_n = 95% F_{nnom}	Essentially not affected.	None
			Landing: Not applicable	Not applicable	Not applicable	Not applicable	None
		b. Failure to full increase authority	SLTO: Not affected, this adjustment has not authority at SLTO.	Not affected	Not affected	Not affected	None
			During climb above 240°F T_{t2} duct nozzle area larger than nominal.	Duct nozzle area larger than nominal. Lose remote duct nozzle adjustment capability.	Total engine airflow larger than nominal.	Essentially not affected if inlet system can accommodate increased total engine airflow.	None
			Cruise: Duct nozzle area larger than nominal.	Duct nozzle area larger than nominal. Lose remote duct nozzle adjustment capability.	Total engine airflow larger than nominal. F_n 95% F_{nnom}	Essentially not affected if inlet system can accommodate increased total engine airflow	None
			Landing: Not applicable	Not applicable	Not applicable	Not applicable	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

No.___ of____

Component Sense or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
12. Manual Remote Total Airflow Adjustment (Continued)		c. Loss of power supply.	SLTO: No immediate effect. Lose remote duct nozzle adjustment capability.	Lose remote duct nozzle adjustment capability.	No immediate effect. Lose remote duct nozzle adjustment capability.	No immediate effect.	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	No immediate effect.	None
			Landing: Not applicable	Not applicable	Not applicable	Not applicable	None
13. Fan Discharge Total Pressure (P_{t3}) Sense to Unitized Control or Fan Discharge Static Pressure (P_{s3}) Sense to Unitized Control	P_{t3} and P_{s3} senses are utilized to sense fan pressure ratio $(P_{t3}-P_{s3})/P_{t3}$ for use in controlling total engine airflow.	a. Partial loss of P_{t3} sense.	SLTO: Fan pressure ratio sense to control will be lower than actual ratio. Duct nozzle area larger than normal with increase dependent on amount of P_{t3} sense loss.	Duct nozzle area larger than normal.	Some increase in N_1 and total engine airflow with increase dependent on amount of P_{t3} sense loss.	Not affected	None.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	If desired, adjust nozzle position with remote duct nozzle adjustment.
			Landing: Not affected	None	Not affected	Not affected	None
		b. Partial loss of [illegible]3 sense.	SLTO: Fan pressure ratio sense to control will be higher than actual ratio. Duct nozzle area less than normal with decrease dependent on amount of P_{s3} sense loss.	Duct nozzle area smaller than normal.	Some decrease in N_1 and total engine airflow with reduction dependent on amount of P_{s3} sense loss.	Not affected	None.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	If desired, adjust nozzle position with remote duct nozzle adjustment.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	None
		c. Complete or significant loss of P_{t3} sense.	SLTO: Fan pressure ratio sense to control willbe significantly lower than actual. Duct nozzle area increases to maximum.	Duct nozzle area increase to wide open.	Total engine airflow increased. N_1 higher than normal. F_n = 90% F_{nma}.	AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 85% F_{nma}.	If total engine airflow correction desired, AF.	If total engine airflow correction desired, adjust manual remote EPR control or reduce PLA and adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Landing: Not affected	Not affected	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.

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Sheet I

JTF17 FAILURE MODE & EFFECT ANALYSIS

No.__ of___

Component Sense or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
13. Fan Discharge Total Pressure (P_{t3}) Sense to Unitized Control or Fan Discharge Static Pressure (P_3) Sense to Unitized Control (Continued)		d. Complete or significant loss of P_{s3} sense.	SLTO: Fan pressure ratio sense to control will be significantly higher than actual. Duct nozzle area decreased to minimum area.	Duct nozzle area to minimum value. Engine surge during augmentation.	Engine surge. After surge PLA correction: F_n = 65% F_{nma}	AP	Reduce to and or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 20% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	If maximum F_n desired, same as SLTO.	Not affected.	None. If maximum F_n desired, same as SLTO.
14. Duct Nozzle Area Feedback Signal to Unitized Control	Duct nozzle actual area sense utilized to control duct nozzle area.	Complete loss of duct nozzle area feedback signal.	SLTO: Duct nozzle scheduled to full open position.	Duct nozzle area to full open position.	Total engine airflow increased N1 higher than normal. F_n = 90% F_{nma}.	AP	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 85% F_{nma}.	Same as SLTO	Same as SLTO. If total engine airflow correction desired, adjust manual remote EPP control or reduce PLA and adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Landing: Same as SLTO. If maximum F_n desired, same as SLTO.	Same as SLTO	Some F_n reduction. If maximum F_n desired, same as SLTO.	Essentially not affected.	None. Increase PLA if desired. If maximum F_n desired, same as SLTO.
15. Electrical Power Supplies to Ignition Exciters (2 Gas Generator and 1 Duct Heater Supplies)	Source of electrical energy for spark ignition of gas generator and duct heater.	a. Loss of one power supply to gas generator circuit.	SLTO: Not affected. Redundant gas generator ignition system supply.	A voltage signal generator is provided in each exciter to check each of the redundant gas generator circuits.	Not affected. Relight capability of gas generator assured by redundant system.	Not affected	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
		b. Loss of power supply to duct heater circuits.	SLTO: Lose duct heater ignition capability.	A voltage signal generator is provided in each exciter to check duct heater circuits.	Not affected when failure occurs during duct heater operation.	Not affected	None
				After duct heater shutoff, it cannot be relit.	After duct heater shutoff, it cannot be reignited. F_n = 65% F_{nma}.	AP	Maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense or Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
15 Electrical Power Supplies to Ignition Exciters (2 Gas Generators and 1 Duct Heater Supplies) (Continued)			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except if duct heater shutoff: F_n = 20% F_{nmax}.	Same as SLTO	Same as SLTO
			Landing: Not affected. Duct heater ignition is not available.	Not affected	Not affected. Maximum available F_n limited to SLTO conditions.	Not affected	None. Same as SLTO if maximum F_n desired.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense and Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
16. Gas Generator Manifold Drain Valve Signals							
a. Gas Generator Fuel Pump Interstage Pressure	Provides positive force to actuate and hold valve piston in overboard drain closed position.	Loss of pressure.	SLTO: Gas generator manifold drain valve will open the overboard drain port. Most of the gas generator fuel flow will be lost through the overboard drain.	Marked reduction in N_2, T_{t7}, and EPR. Engine may not sustain itself. Excessive overboard drain leakage from gas generator manifold drain valve.	Marked reduction in N_1, N_2, T_{t7}, and EPR. N_2 will be near idle or the engine may not sustain itself.	IFS	Reduce SOL to off position. Adjust F_n level on unaffected engines to obtain desired aircraft conditions
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
b. Positioning Signal Fuel Pressure from Unitized Control	Signal level determines drain valve positioning. High pressure for overboard drain open and low pressure for overboard drain closed.	Loss of pressure or loss of high pressure capability.	SLTO: Not affected	Not affected	Not affected	Not affected	None
			Cruise: Not affected	Not affected	Not affected	Not affected	None
			Landing: Not affected. On engine shutdown residual fuel will not be drained from the gas generator manifold.	Not affected. On engine shutdown no fuel dump from gas generator overboard drain	Not affected. May have shutdown fire in gas generator combustion section	Not affected	None. If have shutdown fire, motor engine on starter with SOL in off position
17. Duct Heater Zone 1 Manifold Drain Valve Signals							
a. Gas Generator Fuel Pump Interstage Pressure	Provides positive force to actuate and hold valve piston in the overboard drain closed position.	Loss of pressure.	SLTO: Duct heater Zone 1 manifold drain valve will open the overboard drain port. Fuel flow to Zone 1 manifold will be erratic due to fuel flow in system comprised of intermittent gas generator pump interstage fuel plus duct heater metered fuel flow with a large portion of the total fuel flow being dumped through the overboard drain. Duct heater metered fuel flow intermittently reduced to minimum value. Total airflow bias reset intermittently activated	Intermittent reduction in duct heater fuel flow and duct nozzle excursions. Excessive overboard drain leakage from Zone 1 manifold drain valve.	Erratic duct burner operation. At nonaugmented PLA: F_n = 65% F_{nmax}.	AF	Reduce to and maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 20% F_{nmax}.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense and Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
*b. Positioning Signal Fuel Pressure from Unitized Control	Signal level determines drain valve positioning. High pressure for overboard drain open and low pressure for overboard drain closed.	Loss of pressure or loss of high pressure capability.	SLTO: Not affected during duct heater operation.	None	Not affected	Not affected	None
			On duct heater shutoff, residual fuel will not be drained from the Zone I manifold.	On duct heater shutoff, no fuel dump from duct heater Zone I manifold.	Eventual coking of Zone I fuel nozzles.	Not affected	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	None
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. Maximum F_n is available if desired.	Not affected	None
18. Duct Heater Zone II Manifold Drain Valve Signals							
*a. Gas Generator Fuel Pump Interstage Pressure	Provides positive force to actuate and hold valve piston in overboard drain closed position.	Loss of pressure.	SLTO: Duct heater Zone II manifold drain valve will open the overboard drain port at augmented levels above zone transfer. Fuel flow to Zone II manifold will be comprised of intermittent gas generator pump interstage fuel plus duct heater metered fuel flow with a large portion of the total fuel flow being dumped through the overboard drain. Zone I metered fuel flow intermittently varied. Duct heater fuel flow intermittently reduced. Total airflow bias reset intermittently activated.	At augmented PLA range above zone transfer, intermittent reduction in duct heater fuel flow and duct nozzle excursions. Excessive overboard drain leakage from Zone II manifold drain port.	Erratic duct burner operation at zone transfer and above. At zone transfer: F_n = 90% F_{nmax}.	AF	Reduce to and/or maintain Zone I augmentation PLA range or lower. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Normally not affected.	None	Normally not affected.	Normally not affected.	None
			If PLA range above zone transfer desired, same as SLTO.		If PLA range above zone transfer desired, same as SLTO except: F_n = 80% F_{nmax}.		If PLA range above zone transfer desired, same as SLTO.
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
*b. Positioning Signal Fuel Pressure from Unitized Control	Signal level determines drain valve positioning. High pressure for overboard drain open and low pressure for overboard drain closed.	Loss of pressure or loss of high pressure capability.	SLTO: Not affected during duct heater Zone II operation.	None	Not affected	Not affected	None
			On duct heater reduction to Zone II shut off, residual fuel will not be drained from Zone II manifold.	On Zone II shutoff, no fuel dump from Zone II overboard drain.	Eventual coking of Zone II spraybars.	Not affected	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sensor and Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
18. Duct Heater Zone II Manifold Drain Valve Signals			Cruise: Normally not affected. If PLA in the above zone transfer desired, same as SLTO.	None	Normally not affected. If PLA range above zone transfer desired, same as SLTO.	Not affected	None
b. Positioning Signal Fuel Pressure from Unitized Control (Continued)			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None
19. Remote T_{t2} Sensor Signals							
a. Modulated Fuel Pressure Signals to Unitized Control	Fuel pressure is modulated by each remote sensor so that each signal is proportional to T_{t2}.	Loss of one signal pressure.	SLTO: Not affected. The redundant T_{t2} system selects the higher of the two remote sensor signals.	An indicating flag is provided to indicate when one T_{t2} sensor system has failed.	Not affected	Not affected	None
			Cruise: Same as SLTO	Same as SLTO	Not affected	Not affected	None
or			Landing: Same as SLTO	Same as SLTO	Not affected	Not affected	None
b. Drain Fuel Pressure Reference from Unitized Control	Low pressure reference sink for modulating signal pressure.	Loss of pressure to one sensor.					
20. Remote Duct Heater Turbopump Controller Signals							
a. Decrease Pump Speed Fuel Pressure Signal from Unitized Control	Modulated fuel pressure signal to one end of butterfly valve actuator. This signal level increased to reduce duct heater fuel pressure level by reducing butterfly opening in air supply to turbopump turbine.	Loss of pressure.	SLTO: Butterfly valve positioned to maximum position. Pump speed is increased and duct heater fuel system pressure level is increased.	Ground check of butterfly valve position indicator will show butterfly valve open at engine shutdown and all nonaugmented engine operating conditions.	Not affected. Duct heater control will maintain proper fuel scheduling.	Not affected	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	None
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Not affected	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense and Signal Failures (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
20. Remote Duct Heater Turbo-pump Controller Signals (Continued)							
*b. Increase Pump Speed Fuel Pressure Signal from Unitized Control	Modulated fuel pressure signal to one end of butterfly valve actuator. This signal level increased to increase duct heater fuel pressure level by reducing butterfly opening in air supply to turbopump turbine.	Loss of pressure.	SLTO: Butterfly valve positioned to minimum position. Pump speed reduced to low level. Duct heater fuel flow reduced to essentially zero.	Duct heater fuel flow essentially zero. Duct heater shut off if on or cannot be initiated if off.	F_n = 65% F_{nma}	AF	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 20% F_{nma}. In addition, oil temperature will increase and may eventually exceed limits due to loss of duct heater oil cooler fuel flow.	Same as SLTO. Also, may have IFS.	Same as SLTO. In addition, monitor engine oil temperature. It may be necessary for IFS and to reduce aircraft speed to subsonic condition to prevent exceeding oil temperature limit.
			Landing: Same as SLTO	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
21. Compressor Inlet Guide Vane Accuator Signals							
*a. Start-Cruise Positioning Fuel Pressure Signal from Unitized Control	Signal level of this signal and the SLTO positioning fuel pressure signal determine compressor inlet guide vane position. Start-cruise signal level high and SLTO signal low for start-cruise position. The signals are reversed for SLTO position.	Loss of pressure.	SLTO: Not affected. Compressor inlet guide vane positioning to normal schedule will be maintained by SLTO signal.	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None

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Component Sense and Signal Failure (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
21. Compressor Inlet Guide Vane Actuator Signals (Continued)							
*b. SLTO Positioning Signal from Unitized Control	See previous functional description for start-cruise signal.	Loss of pressure.	SLTO: Compressor inlet guide vanes go to start-cruise position.	N_2 higher than normal. Duct nozzle area less than normal. During augmentation engine will surge.	F_n = 40% F_{nna}	AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: No immediate effect.	None	No immediate effect.	No immediate effect.	None
			On descent, the compressor inlet guide vanes will remain at the start-cruise position.	During descent at normal SLTO position of compressor inlet guide vanes: Minor increase in N_2 and decrease in duct nozzle area at lower three-fourths of nonaugmented PLA range.	At lower three-fourths nonaugmented PLA range, engine not appreciably affected.	Not appreciably affected.	None
				At upper quarter of nonaugmented PLA range, N_2 increases and duct nozzle area decreases as altitude and T_{t2} decrease.	Some reduction in F_n with reduction becoming larger as altitude and T_{t2} decrease.	AF and CR	Adjust F_n level on affected engine.
				At augmented PLA range, N_2 increase and duct nozzle decrease with eventual engine surge as altitude and T_{t2} decrease.	Some reduction in F_n with reduction becoming larger as altitude and T_{t2} decrease. Eventual engine surge limiting F_n to less than normal maximum nonaugmented.	Same as above	Adjust F_n level on affected engine and F_n level on unaffected engines to obtain desired aircraft conditions. Affected engine eventually limited to nonaugmented PLA range.
			Landing: Not affected at N_2 level where compressor inlet guide vanes normally in start-cruise position.	None	Not affected	Not affected	None
			At N_2 level where compressor inlet guide vanes normally in SLTO position, the vanes w[illegible] to the start-crui[illegible]ion.	Duct nozzle area less than normal. N_2 higher than normal with deviation greater at high PLA range. Engine will surge if augmentation attempted.	F_n = 40% F_{nma}. Reverse F_n lower than normal.	AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense and Signal Failure (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
22. Remote Compressor Bleed Control Signals							
a. Compressor Discharge Air Pressure Supply to Remote Bleed Control or Positioning Air Signal to Compressor Bleed Actuators	Air pressure source ported to compressor bleed actuators to open the bleed valves.	Loss of supply pressure.	SLTO: Not affected. Compressor bleeds remain in closed position.	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
	Signal level determines compressor bleed valve position. Compressor discharge air pressure ported to bleed valve actuators open the bleeds. Ambient pressure ported to bleed valve actuators close the bleeds.	Loss of pressure or loss of compressor discharge air pressure porting capability.	Landing: Same as SLTO	Compressor bleeds remain closed when N_2 reduced to idle.	No immediate effect. Engine may surge during acceleration while in reverse or if maximum F_n desired.	No immediate effect. If engine surges, AF.	None. If engine surges, retard PLA to idle or shut off engine. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
*b. Drain Fuel Pressure from Unitized Control	Low level pressure on spring side actuation piston to maintain actuation force on piston when signal pressure at high level.	Loss of pressure.	SLTO: Not affected. Signal level opposed by spring so that proper actuation maintained.	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None
*c. Signal Fuel Pressure from Unitized Control	Signal level determines positioning of compressor bleed valves. High pressure for bleeds closed and low pressure for bleeds open.	Loss of pressure or loss of high pressure capability.	SLTO: Compressor bleeds to bleeds open position.	N_2, T_{t7}, and EPR lower than normal.	F_n = 70% F_{nna}	AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 80% F_{nna}	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
23. Reverser-Suppressor Actuator Signals							
a. Positioning Signal Fuel Pressure from Unitized Control	Signal level determines reverser-suppressor positioning. Hydraulic pressure for reverse position and gas generator pump inlet pressure for forward position.	Loss of pressure or loss of high pressure capability.	SLTO: Not affected	None	Not affected	Not affected	None
			Cruise: Not affected	None	Not affected	Not affected	None
			Landing: Reverser-suppressor actuation to reverse position not available.	Cannot retard PLA below reverse idle.	Reverse thrust not available.	Reverse thrust not available on one engine.	Less reverse desired, maintain engine at idle. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Component Sense and Signal Failure (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
23. Reverser-Suppressor Actuator Signals (Continued)							
*b. Gas Generator Pump Interstage Fuel Pressure	Permits maintaining signal pressure at high level in the reverse position. Assists actuation to forward position when signal pressure reduced to low level and provides holding force in the forward position.	Loss of pressure.	SLTO: Not affected Cruise: Not affected Landing: Not affected	None None Actuation from reverse to forward position may be somewhat slower than normal.	Not affected Not affected Not affected	Not affected Not affected Not affected	None None None

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SECTION II
EFFECTS OF DETAIL PART FAILURES WITHIN COMPONENTS

This section presents the study of the effects of detail part failures within components. While experience with other Pratt & Whitney Aircraft engines has shown the majority of such failures will not occur in service, the probability of each failure is not negligible and may be caused by fuel contamination, detail part distortion, bellows or diaphragm rupture, or sticking of sliding parts. Extensive experience with control system components of the type used in the JTF17 engine has shown that basic parts such as housings, castings, levers, rollers, cams, and springs are designed with sufficient margin to preclude their breakage. In making this study it was assumed that failure of such parts will not occur. Similarly, based on experience, it was assumed that sliding seals used in this design will not incur any significant wear within the specified overhaul period.

The duct heater fuel pump air turbine is similar to a fuel pump used on the J58 engine. The JTF17 duct heater fuel pump air turbine has the following characteristics:

1. The low cycle fatigue design criterion is 100,000 cycles.
2. The maximum normal turbine rotor speed is 27,500 rpm. The vortex venturi turbine exhaust limits turbine overspeed to 41,000 rpm at no load conditions. The turbine burst speed is 85,000 rpm.

3. The turbine and blades are machined from PWA 1005A Waspaloy forging. There are no through holes in the turbine disk.

4. A quality assurance spin proof test to 71,000 rpm will be performed on each finish machined turbine disk prior to assembly of the pump.

In view of the above, fracture of the ·ict heater air turbine was not considered in making this study.

Each failure presented in this section has been assigned a Failure Mode Index number which will be utilized in the future collection of reliability information. Each number defines a unique part of the engine and consists of a series of digits such as 25.2.27.3.xx. This is the number assigned to the integrating piston and pilot valve of the unitized control duct heater fuel turbopump controller system. Such identification is arrived at in the following manner.

25. The first series of digits identifies a particular engine section, in this case the fuel and control system.

.2. The second series of digits identifies a particular assembly within the applicable engine section, in this case the unitized control.

.27. The third series of digits identifies a particular sub-assembly or sub-function within the assembly, in this case the duct heater fuel turbopump controller system.

.3. The fourth series of digits identifies a particular detail part within the sub-assembly, in this case the integrating piston and pilot valve.

.xx. The last series of digits will be used to define the exact nature of the detail part failure such as contamination, galling, fretting corrosion, etc. This last series of digits has not been included in this study since some of the failures presented could be caused by more than one method and the deletion of this digit series was felt to have no significance for this study.

25.1 GAS GENERATOR FUEL PUMP

A. Description

The gas generator pump is an engine driven two-stage unit which incorporates a centrifugal boost stage in series with a single high pressure gear stage. The boost element supplies fuel to the high pressure gear stage, the hydraulic pump inlet, the duct manifold quick-fill system and the ignition exciters for cooling. The high pressure stage supplies fuel to the unitized control where it is properly metered before being injected into the gas generator combustor. A small amount of this flow is also used by the unitized control computer section to power hydraulic servos and generate hydraulic signals.

A 25-micron filter is incorporated at the boost stage discharge and a 200-mesh screen is located within the hydraulic and control bypass return flow path to the gear stage. Bypass valves are located in parallel with the filter and the screen to provide a flow path in the event either become contaminated. An indicator is incorporated which produces a visual indication if the 25-micron filter pressure drop approaches the bypass condition.

A bypass valve is incorporated in parallel with the boost stage which opens in the event of impeller blockage to provide a low restriction flow path to the high pressure section. This will permit the pump to continue to operate on the main stage alone.

A relief valve is included at the pump discharge which opens to prevent excessive pump discharge pressure in event of a downstream malfunction.

Two fuel outlets are provided on the pump. One is connected to the unitized control through the fuel-oil cooler and the other outlet is connected to the control through a flow divider valve.

The flow divider valve directs total pump discharge flow through the fuel-oil cooler until the pressure drop across the cooler reaches 30 psi. All additional flow beyond that required to maintain the 30 psi is bypassed directly to the unitized control. This scheme reduces the size of the cooler and associated plumbing resulting in a total system weight reduction.

Instrumentation pressure taps are provided at the pump inlet, filter inlet, filter discharge and gear stage discharge. These pressure taps may be used to obtain signals for cockpit instrumentation.

The pump drive spline is lubricated by oil supplied under pressure from the engine oil system.

The pump design includes a quick-disconnect adaptor plate to which all the external fuel connections, except the main inlet, are made. This feature permits the pump to be removed from the engine without disconnecting the associated plumbing, and to assure the pump can be replaced on an installed engine in less than 30 minutes.

A schematic diagram and a cross-section view of the pump is presented following the analysis of the pump.

JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet 1
B. ANALYSIS
25.1 Gas Generator Fuel Pump

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Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Boost Impeller 25.1.1	To prevent cavitation in the fuel supply to the gear stage and the hydraulic pump by increasing engine inlet fuel pressure for supply to these two fuel pumping elements. Also supplies fuel for duct heater manifold rapid fill and cooling fuel for ignition exciters.	Impeller pumping failure	SLTO: Fuel supply pressure to gas generator fuel pump gear stage and to hydraulic pump decreases to engine inlet fuel pressure. Lose duct heater quick-fill system and cooling flow to ignition exciters.	No immediate effect. Unable to reinitiate duct heater.	No immediate effect. Duct heater cannot be reinitiated after shutoff. For this later condition: $F_n = 65\% F_{nma}$	No immediate effect AF and CR	None. If duct heater shut off, then maintain PLA in nonaugmented range and adjust F_n level on unaffected engines to obtain desired aircraft conditions
			Cruise: Same as SLTO	Same as SLTO	No immediate effect. Duct heater cannot be reinitiated after shutoff. For this later condition: $F_n = 20\% F_{nma}$	Same as SLTO	Same as SLTO
					Also, after prolonged high M_n operation, may lose gas generator relight capability due to lack of cooling flow to ignition exciters	May result in IFS.	In the event of gas generator flameout followed by inability to relight, follow inflight engine shutdown procedure.
			Landing: Not affected. Duct heater fuel flow not available.	Not affected. Will not be able to reinitiate duct heater.	Not affected. Maximum available F_n limited $F_n = 65\% F_{nma}$	Not affected	None. Same as SLTO if maximum F_n desired
Gear Pump 25.1.2	Supplies high pressure fuel to the gas generator control.	Gear pumping failure	SLTO: Complete loss of gas generator fuel flow and resultant duct heater shut off.	Gas generator and duct heater flameout. No gas generator fuel flow indication if relight attempted.	Gas generator and duct heater flameout	IFS and CR	In-flight engine shut down. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Complete loss of gas generator fuel flow and resultant duct heater shut off. Insufficient fuel flow to engine oil coolers.	Same as SLTO.	Gas generator and duct heater flameout. Engine oil temperature will increase and may exceed limits.	Same as SLTO	In-flight engine shut down. If necessary to maintain oil temperature limits, reduce aircraft speed to subsonic conditions.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Gas Generator Fuel Pump (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Interstage Filter (25 micron) 25.1.3	Contamination protection. Filters boost impeller discharge fuel flow.	Excessive contaminant deposited in filter.	SLTO: When fuel pressure drop across the filter exceeds a preset level, the filter bypass valve opens allowing fuel to bypass the filter. This permits contamination to enter the fuel and control system which may cause pump and control system deterioration depending on the contaminant.	None in flight. An external visual indicator is provided on the pump that is activated at a filter pressure drop level lower than the filter bypass valve opening level.	No immediate effect	No immediate effect CR	None Excessive contaminant in the filter and corrective action can be controlled in most instances by normal ground inspection and maintenance.
			Cruise: Same as SLTO	Same as SLTO	No immediate effect	No immediate effect	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	No immediate effect	No immediate effect	Same as SLTO
Control Bypass Return and Hydrauli. System Return Strainer (200 mesh) 25.1.4	Contamination protection. Strains return to interstage fuel flow from the control bypass and hydraulic system return.	Excessive contaminant deposited in strainer.	SLTO: When fuel pressure drop across the strainer exceeds a preset level, the strainer bypass valves open allowing fuel to bypass the strainer. This permits contamination to enter the fuel and control system which may cause pump and control system deterioration depending on the contaminant.	Excessive contaminant in the strainer and corrective action can be controlled in most instances by normal periodic inspection and maintenance.	No immediate effect	No immediate effect	None
			Cruise: Same as SLTO	None	No immediate effect	No immediate effect	Same as SLTO
			Landing: Same as SLTO	None	No immediate effect	No immediate effect	Same as SLTO
Boost Impeller Bypass Valve 25.1.5	Provides a direct bypass path around the boost impeller in the event of boost impeller pumping failure.	Seizure (closed position)	SLTO: No first order effect. In the event of a boost impeller pumping failure (double failure) the fuel supply to the gear stage will be through the impeller instead of a direct bypass path resulting in an increase in the pressure drop through the impeller stage.	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet I
Gas Generator Fuel Pump (Continued)

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Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gear Pump Relief Valve 25.1.6	Provides fuel pressure relief to limit gas generator fuel system pressure to a maximum safe level in the event of abnormalities that otherwise would result in excessive system fuel pressure.	Seizure (closed position)	SLTO: No first order effect. In the event of abnormalities in the gas generator fuel system resulting in an increase in system pressure (double failure) the system pressure level could become excessive.	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None
Oil Cooler Fuel Bypass Valve 25.1.7	Provides variable fuel bypass for the gas generator oil cooler in order to ensure proper fuel flow through the oil cooler for heat transfer commensurate with oil cooler size and pump discharge fuel pressure level.	a) Seizure in closed position.	SLTO: All pump discharge fuel is directed through the gas generator oil cooler. Pump discharge fuel pressure level is increased approximately 300 psi. Increase in pressure will not result in pump relief valve opening. Normal fuel scheduling will be maintained.	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO, except pump discharge pressure increases less at this reduced engine speed condition.	None	Not affected	Not affected	None
		b) Seizure in open position.	SLTO: Gas generator oil cooler bypass fuel flow path remains open at all conditions. Fuel flow through oil cooler will remain adequate.	None	Not affected. Oil cooler fuel flow is adequate for oil cooling.	Not affected	None
			Cruise: Same as SLTO	None	Same as SLTO	Not affected	None
			Landing: Same as SLTO	None	Same as SLTO	Not affected	None

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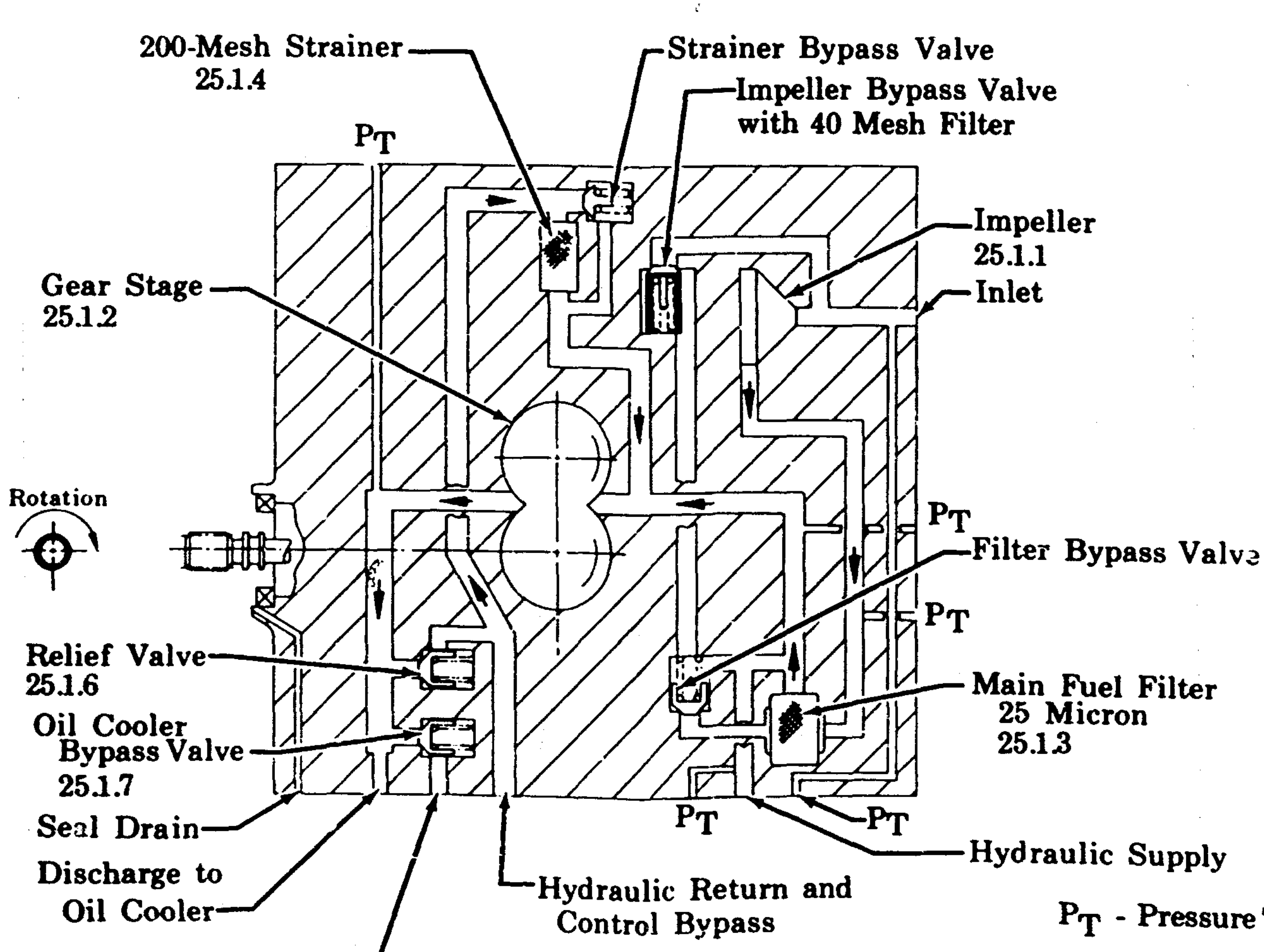
Gas Generator Fuel Pump



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25.2 UNITIZED FUEL AND AREA CONTROL

A. Description

The unitized fuel and area control is the major component of the control system for the JTF17 engine and incorporates all of the primary and most of the secondary controlling functions of the system.

The JTF17 engine control has the following basic functions:

1. Controls engine speed, turbine inlet temperature, and engine thrust between full reverse and maximum duct augmentation power as a function of PLA.

2. Schedules gas generator fuel flow rates during acceleration or deceleration to keep engine operating conditions within acceptable limits during transient operations.

3. Positions the duct heater exhaust nozzle area to maintain the design corrected total engine airflow schedule.

4. Positions the high compressor inlet guide vanes as a function of engine inlet temperature and high rotor speed.

5. Positions the compressor bleeds as a function of high rotor speed and engine inlet temperature.

6. Positions the thrust reverser-suppressor as a function of power lever angle.

7. Provides for fuel cutoff at engine shutdown.

8. Controls the speed of the duct heater fuel pump to the minimum required to provide duct fuel pressure and flow.

The main component of the control system houses all of the engine control functions described above and is referred to as the unitized control. Four separately mounted components are utilized. These components are:

1. A turbopump controller signaled by the unitized control to control duct heater fuel pump air supply by modulating a butterfly valve located in the pump air inlet supply.

2. Two engine inlet temperature sensors which sense temperature with gas-filled tube. The resultant gas pressure is transduced into a fluid pressure and in turn sensed by the unitized control for use as engine inlet temperature bias.

3. A compressor bleed control valve which ports compressor discharge pressure or nacelle ambient pressure to the compressor bleed actuator as signaled by the unitized control.

The unitized control is supplied with fuel pressure and flow by three pumps: (1) a gear-type pump to supply fuel to the gas generator, (2) a centrifugal fuel pump to supply fuel to the duct heater, and (3) a piston-type pump to provide hydraulic pressure for duct heater exhaust nozzle and reverser-suppressor clamshell operation.

Power command inputs from the airframe to the unitized control are mechanical and consist of a single lever controlling forward and reverse thrust, and a separate lever controlling fuel cutoff. Remote setting of pressure ratio is provided to permit adjustment of gas generator pressure ratio in the maximum nonaugmented and the augmented regions.

The unitized control performs all the required computing functions in one cam linkage system that responds to input signals from the aircraft and engine. Fuel is metered to the gas generator to set the desired engine pressure ratio (EPR) for both augmented and nonaugmented operation. Fuel is metered to the duct heater to set the desired thrust augmentation. The duct heater exhaust nozzle is positioned to provide control of total engine airflow. Schedules are included to sequence the (1) reverser-suppressor system, (2) high compressor inlet guide vanes position, (3) compressor bleed position, and (4) duct heater ignition system.

The scheduled gas generator fuel flow is metered by the throttle valve, which is positioned by the computer portion of the unitized control in response to the input signals. A constant pressure drop is maintained across this valve by the pressure regulating valve which bypasses excess fuel back to pump interstage pressure.

To protect the system from excessive fuel temperature, a thermal control is incorporated in the unitized control. This opens a supplementary bypass port when the fuel temperature at the control inlet exceeds 300°F for gas generator flows of less than 5000 pph and 360°F for gas generator flows greater than 5000 pph. This bypassed fuel is returned to the aircraft system as required to prevent excessive temperature in the engine fuel system.

Fuel is metered to the gas generator burner in response to power lever and computer system inputs when the shutoff lever is in the fuel "on" position.

Starting, accelerating, speed governing, and decelerating schedules are used to regulate this flow to protect the engine from overtemperature and overstress at all times. For starting and acceleration to the desired speed, an acceleration scheduling cam is provided. The cam is translated by high rotor speed and is rotated by engine inlet temperature. The cam contour provides a schedule of fuel/air ratio (W_f/P_b) that is multiplied by primary combustor pressure, (P_b), to provide fuel flows to safely accelerate the engine in the minimum time. Overspeed protection is provided for the high speed rotor by a steep overspeed droop slope in the acceleration cam.

At all power settings below those that require maximum turbine temperature, the gas generator fuel flow is regulated by a proportional governor which senses high rotor speed. This governed speed is selected by the power lever angle and biased by engine inlet temperature. At idle, the governed speed can be adjusted with a manual ground adjustment on the unitized control to permit trimming of engine idle speed.

At steady-state maximum nonaugmented and all augmented conditions the gas generator fuel/air ratio is scheduled as a function of engine inlet temperature and high rotor speed to provide the desired engine pressure ratio. The delivered fuel can be manually adjusted if desired to permit adjusting gas generator pressure ratio in the duct augmented range and maximum nonaugmented range.

The high compressor inlet guide vanes are positioned in one of two positions by a hydraulic fuel actuator. Cruise and takeoff positions are automatically scheduled as a function of high rotor speed and engine inlet temperature.

The compressor bleed actuators are positioned by pneumatic pressure directed by an externally mounted control valve which is signaled by fluid pressure signals from the unitized control. Bleeds open and closed positions are automatically scheduled as a function of high rotor speed and engine inlet temperature.

The reverser-suppressor is actuated by hydraulic fuel actuators. Takeoff and reverse positions are selected by power lever positions.

The desired duct fuel flow is scheduled by the duct control metering valve. A throttling type regulating valve maintains a constant pressure drop across the metering valve. To minimize the amount of throttling required in the unitized control, and heat rejection to the fuel, the air supply to the duct heater turbopump is modulated to vary pump rpm as required to hold a constant pressure drop across the complete duct fuel control metering section at all engine power settings.

Fuel is metered to the duct heater as a function of power lever position and engine inlet temperature. Power lever translates a 3-D cam and engine inlet temperature rotates the cam, the output of which is the desired duct heater fuel flow burner pressure ratio (W_f/P_b). This ratio is multiplied by burner pressure (P_b) resulting in a signal proportional to fuel flow being generated.

The duct heater incorporates two zones of fuel injection. Within the unitized control, each zone is provided with a fuel shutoff valve and a manifold rapid fill system. This latter system reduces by a very significant amount the time required for augmentor transients by providing a high rate of fuel flow from the gas generator boost pump during the fill period. Each zone is also provided with separate fuel pressure signals for operating the fuel manifold dump valves.

When the power lever is advanced beyond the maximum nonaugmentation flat to the minimum duct augmentation flat, a sequencing valve in the unitized fuel control initiates the following events: (1) the Zone I manifold dump valve closes, (2) the Zone I rapid-fill valve opens, (3) the Zone I shutoff valve opens, (4) the duct exhaust nozzle resets partially open, and (5) the duct igniters are energized. Fuel is delivered to the Zone I fuel manifold at a high flow rate until a pressure signal indicates the manifold is full. The rapid fill valve closes, the igniters are turned off, and the duct exhaust nozzle reset is removed.

Further power lever advancement increases duct fuel/air ratio and duct nozzle area on a coordinated schedule to hold the total engine airflow constant. If the power lever is moved to the Zone II range the (1) Zone II fuel manifold dump valve is closed, (2) Zone II shutoff valve is opened, and (3) Zone II rapid-fill valve is opened to fill the Zone II fuel manifold. A constant fuel/air ratio is held during the Zone II rapid-fill transient. Pressure increasing in the Zone II manifold provides a signal resulting in a closing of the rapid-fill valve and simultaneously routing metered fuel to the Zone II manifold. Total duct fuel flow is divided between Zone I and Zone II by the fuel nozzle flow characteristics. Zone II fuel ignites spontaneously when the fuel enters the burner. Continued power lever advancement causes increased duct heater fuel flow, increased engine thrust, and increased duct nozzle area to maintain constant engine airflow. Maximum duct augmentation is scheduled by power lever position. Fuel flow for quick filling of both the Zone I and Zone II fuel manifolds is supplied from interstage pressure of the gas generator fuel pump.

The total corrected engine airflow is controlled as a function of engine inlet temperature to the schedule defined in the engine specification. The airflow control is achieved by actuating the variable duct exhaust nozzle. In the cruise range the nominal airflow schedule may be manually adjusted by the flight crew between maximum and minimum limits to obtain optimum inlet performance.

Total engine airflow is the sum of gas generator airflow and duct airflow. Gas generator airflow is determined by sensing high rotor speed and engine inlet temperature. Knowing this airflow permits determining the duct airflow required to obtain the desired total engine airflow. Therefore, desired duct airflow will be scheduled as a function of high rotor speed and engine inlet temperature.

The duct corrected airflow is measured using the duct pressure ratio parameter, this being the difference between fan discharge total pressure and fan discharge static pressure divided by fan discharge total pressure, $(P_{t3}-P_{s3})/P_{t3}$. The unitized control schedules the duct pressure ratio necessary to obtain the desired duct airflow. The actual duct pressure ratio is determined by the unitized control and compared with the scheduled pressure ratio. The difference between the pressure ratios initiates corrective action through a proportional plus integral servo and a power boost servo to reposition the duct exhaust nozzle as required in a closed loop basis to obtain the desired duct airflow.

A schematic of the unitized control is presented following the analysis of the control.

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B. ANALYSIS
25.2 Unitized Control

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Shutoff Lever Sequencing Valve 25.2.1.1	Provides arming and signaling for all shutoff valve and drain valve functions.	Seizure	SLTO: Not affected	None	Not affected	Not affected	None
			Cruise: Not affected	None	Not affected	Not affected	None
			Landing: Not affected. Engine can be shut off with SOL due to mechanical connection of sequencing valve. SOL torque will increase.	SOL torque increase to shut off engine.	Not affected	Not affected	None
Power Lever Boost and Sequencing System 25.2.2	Provides, with minimum input torque, control of gas generator speed and power level and control of augmentation. Also provides sequencing of reverser-suppressor.						
Power Lever Boost Control Valve 25.2.2.1	Controls the power piston position as a function of input PLA.	Seizure	SLTO: Not affected. Control system PLA function to control maintained by mechanical drive of PLA cam shaft either through the seizure or by the override torque key. Torque required to move PLA will increase.	Increase in PLA input torque.	N.. affected	CR	None
			Cruise: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None
Power Lever Boost Power Piston 25.2.2.2	Provides power boost rotation of PLA cam shaft in response to PLA input through control valve.	Seizure	SLTO: Control system remains at setting existing at time of failure. T_{t2} bias of schedules will continue to function.	No control of engine power setting.	Engine power remains at setting existing at time of failure. T_{t2} bias of power setting continues to function.	CR. If additional power desired, AF.	None at conditions existing at time of failure. If power change desired, adjust F_n level on unaffected engines to obtain desired aircraft conditions. Engine can be shut down with SOL.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO. In addition, reverser-suppressor actuation not available.	Same as SLTO	Same as SLTO. In addition, reverse thrust not available.	Same as SLTO	Same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
PLA Sequencing Valve 25.2.2.3	Provides sequencing of reverser-suppressor, duct heater initiation, and duct heater zone transfer.	a) Seizure in zone transfer position.	SLTO: Control system not affected at PLA setting at time of failure (Zone I - Zone II transfer) and higher.	None	Not affected	None	None
			As PLA is reduced below zone transfer, Zone II fuel flow continues and lowers Zone I fuel flow below normal. On subsequent PLA advance to zone transfer or higher, the normal airflow bias signal to the total airflow reset piston will not occur.	Normal engine total airflow increase during zone transfer will not occur.	As PLA reduced, eventual Zone II flameout. Zone I fuel flow lower than normal with F_n lower than normal. Readvancing PLA will result in restoring Zone II augmentation before zone transfer PLA position.	CR	Advance PLA to near zone transfer or higher to restore normal augmentation. Adjust F_n level on unaffected engine to obtain desired aircraft conditions.
			Duct heater fuel flow cannot be shut off with PLA until PLA reduction results in 80% N_2 or lower. Subsequent N_2 increase above 80% will reinitiate duct heater fuel flow.	Duct heater cannot be shut off with normal reduction to maximum nonaugmented position.	Duct heater shutoff requires reduction to 80% N_2 or lower. Subsequent increase in N_2 above 80% will reinitiate duct heater.	Same as above	If duct heater shutoff desired, reduce N_2 with PLA
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not applicable. If duct heater initiated and failure occurs, same as SLTO. In addition, cannot activate reverser-suppressor.	Not applicable	Not applicable. If duct heater initiation and failure occurs, same as SLTO. In addition, reverse F_n not available.	Not applicable	Not applicable. If duct heater initiated and failure occurs, same as SLTO.
		b) Seizure in any position other than a) above.	For seizure in any position other than in zone transfer position described above, PLA authority will be maintained in an increasing direction due to PLA boost system and mechanical override driving the sequencing valve in an increasing direction. For seizures up to a maximum nonaugmented PLA position, the only effect will be the inability to obtain reverse thrust. For seizure in the Zone I augmented range, the analysis of (a) above will apply except for PLA reduction below zone transfer.				

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25.2 Unitized Control

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Compressor inlet temperature sensing system (2 sensors remote mounted) 25.2.3.	Senses compressor inlet temperature (T_{T2}) with dual remote mounted sensors and utilizes the sense to provide T_{T2} bias of various cams.						
Remote T_{T2} Sensor Gas Filled Bulb 25.2.3.1	Gas pressure in the bulb changes as a direct function of T_{T2}. The gas pressure level is utilized to modulate a flapper valve in the remote sensor thereby transmitting a fuel pressure signal to the control as a function of T_{T2}.	Loss of charge	SLTO: The affected sensor system fails to the complete cold level. Control system is not affected, since the redundant T_{T2} system selects the higher of the two sensor systems.	An indicating flag is provided to indicate when one T_{T2} sense system has failed.	Not affected.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Not affected.	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Not affected.	Same as SLTO	None
or							
Remote T_{T2} sensor compensating bellows 25.2.3.4	Compensates for fuel temperature change effect on the motor bellows. Also provides system damping.	Loss of gas charge					
or							
Remote T_{T2} sensor flapper lever bellows seal 25.2.3.3.	Seals servo fuel in motor bellows cavity from control drain pressure in compensating bellows cavity	Bellows failure					
or							
T_{T2} fixed orifice 25.2.3.6	Supplies servo fuel to remote sensors	Contamination (Plugged Orifice)					
or							
Remote T_{T2} sensor flapper valve 25.2.3.5.	Controlled by the gas filled bulb and bellows to provide a modulated fuel pressure signal to the control as a function of T_{T2}.	Contamination (open position)					

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Remote T_{T2} sensor flapper valve 25.2.3.5 or Remote T_{T2} sensor motor bellows 25.2.3.2 or T_{T2} pilot valve 25.2.3.9	See previous functional description. Transmits gas filled bulb pressure level to remote sensor flapper valve. Modulates T_{T2} servo piston as a function of T_{T2} (remote sensor signal).	Contamination (closed position) Loss of gas charge (gas section of bellows and bulb fills with servo fuel). Seizure (High T_{T2} position)	SLTO: Control T_{T2} system at maximum hot T_{T2} position. Gas generator fuel flow, duct heater fuel flow, duct nozzle, compressor bleeds, and compressor inlet guide vanes scheduled to maximum hot T_{T2} position. Duct heater fuel flow response rate with PLA is constant at approximately cruise response rate. During augmentation, duct nozzle scheduled to full open position. Compressor bleeds open. Compressor inlet guide vanes to start-cruise position. Gas generator and duct heater fuel flows decreased.	Duct nozzle full open, gas generator fuel flow, duct heater fuel flow, N_2, T_{T7}, and EPR lower than normal.	F_n = 30% F_{nmax}	AP and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			During non-augmentation, same as above except duct nozzle scheduled to 4.5 square feet position.	Same as above except duct nozzle at 4.5 square feet position.	F_n = 25% F_{nmax}. Augmentation may be initiated and F_n increased to value above.	Same as above	Reinitiate augmentation if additional F_n desired.
			Cruise: During augmentation, duct nozzle area larger than normal, gas generator and duct heater fuel flows lower than normal.	Duct nozzle area larger than normal. Gas generator fuel flow, duct heater, fuel flow, N_2, T_{T7}, and EPR lower than normal.	F_n = 85% F_{nmax}	Same as SLTO	Same as SLTO
			During non-augmentation, same as above except duct nozzle scheduled to 4.5 square feet position.	Same as above except duct nozzle at 4.5 square feet position.	F_n = 15% F_{nmax}. Augmentation may be initiated and F_n increased to value above.	Same as SLTO	Same as SLTO
			During descent, compressor bleeds open and compressor inlet guide vanes remain in start-cruise position.	Same as above	Power schedules do not follow normal T_{T2} bias as conditions change.	Same as SLTO	Modulate PLA to obtain desired descent conditions.
			Landing: Same as SLTO	Same as SLTO	Some F_n change. If maximum F_n desired, same as SLTO.	Same as SLTO.	Adjust F_n level with PLA. If maximum F_n desired, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
T_{T2} Pilot Valve 25.2.3.9 or T_{T2} Receiver Bellows 25.2.3.8	See previous functional description Transmits remote sensor modulated pressure signal force to T_{T2} pilot valve.	Seizure (low T_{t2} position) Bellows failure	Control T_{T2} system directed to maximum cold fail safe position. Gas generator fuel flow, duct heater fuel flow, duct nozzle, compressor bleeds, and compressor inlet guide vanes scheduled to maximum cold T_{T2} position. Duct heater fuel flow response rate with PLA is constant at approximately SLTO response rate.				
			SLTO: During augmentation, duct nozzle scheduled to full open position. Gas generator and duct heater fuel flow decreased.	Duct nozzle full open, gas generator fuel flow, duct heater fuel flow, N_2, T_{T7}, and EPR lower than normal.	F_n = 70% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			During non-augmentation, same as above except duct nozzle scheduled to 4.5 square feet position.	Same as above except duct nozzle at 4.5 square feet position.	F_n = 45% F_{nma} Augmentation may be initiated and F_n increased to value above.	Same as above.	Reinitiate augmentation if additional F_n desired.
			Cruise: Same as SLTO except compressor inlet guide vanes positioned to SLTO position	Same as SLTO	Same as SLTO except during augmentation F_n = 70% F_{nma}. During non-augmentation F_n = 10% F_{nma}	Same as SLTO	Same as SLTO. Also, use slower than normal PLA modulation in augmentation range.
			Landing: Same as SLTO	Same as SLTO	Some F_n reduction. If maximum F_n desired, same as SLTO.	Same as SLTO	Adjust F_n level with PLA. If maximum F_n desired, same as SLTO.
T_{T2} Selector Valve 25.2.3.7	Selects highest remote T_{T2} sensor modulated pressure signal for passage to the control T_{T2} system.	Seizure	SLTO: Will pass modulated pressure signal of only one sensor or an average of the two sensors depending on seized position of ball valve. The control T_{T2} system will not be affected unless a sensor failure occurs (double failure).	None	Not affected.	Not affected.	None
			Cruise: Same as SLTO	None	Not affected.	Not affected.	None
			Landing: Same as SLTO	None	Not affected.	Not affected.	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
T_{t2} Servo Piston 25.2.3.10	Positions various cams within the control as a function of T_{t2}.	Seizure	SLTO: T_{t2} servo piston and the T_{t2} positioning of various cams will remain in the position scheduled at time of failure. No affect for conditions existing at time of failure.	Control schedules do not follow normal T_{t2} bias as conditions change.	Not affected	Not affected	None
			During climb, control schedules do not follow normal T_{t2} bias. Gas generator fuel flow higher than normal. Duct heater fuel flow and duct nozzle area lower than normal. Compressor inlet guide vanes remain in SLTO position.	Gas generator fuel flow, N_2, T_{t7}, EPR higher than normal. Duct heater fuel flow and duct nozzle area lower than normal.	T_{t7} will eventually exceed limits without crew action. Engine may surge during augmentation even if T_{t7} limits are maintained with remote EPR control.	Eventually, AF, CR.	When necessary to maintain T_{t7} limit, reduce to and maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: T_{t2} servo piston and T_{t2} positioning of various cams will remain in the position scheduled at time of failure. No affect for conditions existing at time of failure.	None for conditions existing at time of failure.	Not affected	Not affected	None
			During nonaugmented descent and landing at low power settings, no noticeable effects.	Control schedules do not follow normal T_{T2} bias as conditions change.	Power schedules do not follow normal T_{T2} bias as conditions change.	Same as SLTO	Modulate PLA to obtain desired descent conditions.
			If maximum F_n desired during landing, schedules remain at high T_{t2} value.	If maximum F_n desired, gas generator fuel flow, duct heater fuel flow, T_{t7}, EPR, N_2 lower than normal.	Maximum F_n not available. F_n = 50% F_{nma}.	AF and CR	If maximum F_n desired, adjust F_n level on unaffected engines to obtain desired conditions.
			Landing: Not affected	None	Not affected	Not affected	None
T_{t2} Failure Indicator Diaphragm 25.2.3.11	Positions failure indicator detent valve in response to difference between the modulated pressure of each remote T_{t2} sensor.	Diaphragm failure.	SLTO: Modulated pressure signal to control will be the average of both sensors. The control T_{t2} system will not be affected unless a sensor failure occurs (double failure).	T_{t2} sense failure indicator will give false indication that one T_{t2} sense system has failed.	Not affected	Not affected	None
			Cruise: Same as SLTO	Same as SLTO	Not affected	Not affected	None
			Landing: Same as SLTO	Same as SLTO	Not affected	Not affected	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
T_{t2} Failure Indicator Detent Valve 25.2.3.12	Positions and holds display flag to indicate one T_{t2} sense system has failed.	a. Seizure in mid position.	SLTO: This is the normal position indicating both T_{t2} sense systems are functioning properly. In the event of a T_{t2} sense system failure, the failure indicator will not be actuated. Control system not affected unless both T_{t2} sensors fail (double failure).	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None
		b. Seizure in activated position	SLTO: This is a position indicating a failure in one T_{t2} sense system. Control system not affected unless both T_{t2} sense systems fail. (double failure).	T_{t2} sense failure indicator will give false failure indication of one T_{t2} sense system after correction of the failed system.	Not affected	Not affected	None
			Cruise: Same as SLTO	Same as SLTO	Not affected	Not affected	None
			Landing: Same as SLTO	Same as SLTO	Not affected	Not affected	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Speed Sense System 25.2.4	Supplies N_2 speed signal to gas generator speed set system.						
Speed Pilot Valve 25.2.4.1	Controls position of speed servo piston as a function of N_2 speed.	a) Seizure (decrease speed signal side of null)	SLTO: Schedules speed servo piston to zero speed position. Maximum gas generator fuel flow ratio scheduled by zero speed failsafe plateau with translation to plateau generally in decreasing ratio direction. Gas generator fuel flow can be modulated with PLA between idle and maximum failsafe plateau value. Maximum value biased by T_{t2}. Bleeds and inlet guide vanes scheduled by failsafe plateaus. Lose duct heater fuel flow if on or cannot initiate if off.	N_2, T_{t7}, and EPR lower than normal. Reduction in gas generator fuel flow. Duct heater shuts off if on or cannot be initiated if off.	F_n = 35% F_{nma}	AF and CR	Decrease to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 5% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
		b) Seizure (increase speed signal side of null)	SLTO: Schedules speed servo piston to high speed position. Gas generator fuel flow ratio scheduled by overspeed limiting schedule setting minimum ratio. Duct heater shuts off and engine dies. Engine may surge on rundown due to compressor bleeds remaining closed and duct nozzle at full closed position.	Duct heater flames out. Engine dies out. Engine may surge on rundown.	Engine dies out and cannot be restarted.	IFS and CR	Move SOL to off position. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO except engine does not die out. Duct heater shut off.	Duct heater shut off. N_2, T_{t7}, EPR and gas generator fuel flow lower than normal.	F_n = -5% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			During descent, engine dies out.	During descent, engine dies out.	During descent, engine dies out and cannot be restarted.	During descent, IFS and CR.	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Speed Servo Piston 25.2.4.2	Controlled by speed servo to position speed set system cams as a function of N_2.	Seizure	SLTO: Lose speed governing, start-acceleration schedule, and overspeed droop. Gas generator fuel flow ratio schedule can be modulated with PLA from minimum ratio to maximum nonaugmented ratio (or acceleration ratio, whichever is lower) at speed value existing at time of failure. Acceleration fuel flow ratio value biased by T_{t2}.	No immediate effect.	At T_{t2} values of approximately 0°F and higher normal maximum gas generator and augmented schedules will be maintained including T_{t2} bias. During climb engine total airflow slightly increased above normal.	CR	Modulate PLA to obtain desired conditions.
				Engine dies out on normal PLA reduction to idle or slightly above idle positions.	If idle or slightly above idle desired, engine dies out on normal PLA reduction. Subsequent restart may be accomplished by controlling fuel flow with slow PLA movements in high non-augmented PLA range during restart although more than one attempt may be required. Also, normal PLA increases from slightly above idle may result in engine surge or exceeding turbine inlet temperature.	Same as above.	If engine dies out, restart using slow PLA increases to control starting fuel flow. Use slow PLA movements to increase and decrease power requirements in order to avoid die out, surge, and exceeding temperature limits.
			At T_{t2} values less than approximately 0°F, overspeed droop will reduce gas generator to minimum fuel flow ratio schedules.	At T_{t2} values less than approximately 0°F, the engine dies out.	At T_{t2} values less than approximately 0°F, engine dies out.	T_{t2} values less than approximately 0°F, IFS, CR.	Move SOL to off position. Adjust F_n level on unaffected engines to obtain desired aircraft conditions. Engine can be restarted at higher T_{t2} values.
			Cruise: Same as SLTO	Same as SLTO except PLA reduction does not result in engine die out at cruise. Engine will die out on descent at approximately 200°F T_{t2} with low PLA positions.	Same as SLTO except PLA reduction does not result in engine die-out at cruise. Engine will die out on descent at approximately 200°F T_{t2} with low PLA positions.	Same as SLTO	Same as SLTO
			Landing: Same as SLTO.	Same as SLTO	Same as SLTO Maximum available F_n may be limited dependent upon speed existing at time of failure.	Same as SLTO Dependent on speed at time of failure, possibly AF.	Same as SLTO If maximum F_n limited and maximum F_n desired, adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Speed Set and Acceleration Limiting System 25.2.5	Part of gas generator computing section to control gas generator speed, and acceleration through use of PLA, N_2, and T_{t2} signals. This system provides a speed error signal to the fuel flow computation system by comparing PLA set desired θ_{t2} corrected speed to actual corrected θ_{t2} speed. Acceleration fuel flow limiting is also provided to control the gas generator within safe operating limits during accelerations.						

The Failure Mode Index Number for this unitized control system has been reserved in the event of future need. Parts within this system consist of cams, cam shafts, springs, and various linkages which are considered to be designed with sufficient margin to preclude their breakage. It was assumed that failure of the parts within this system will not occur. Failures within other unitized control systems will affect the speed set system and the total effect of such failures including the effect on the speed set system are presented in the analysis of the appropriate system.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Primary Combustor Pressure, P_b, Sense System 25.2.6	Provides a multiplying force proportional to P_b to the gas generator fuel flow computation system.						
P_b Sense Bellows 25.2.6.1. or P_b Evacuated Bellows 25.2.6.2	Transmits P_b pressure level as a force to the P_b multiplying lever. Supplies additive force proportional to ambient pressure so that P_b force transmitted to P_b multiplying lever is a function of P_b absolute pressure level.	Sense bellows rupture or Evacuated bellows leak or rupture	SLTO: Gas Generator effective P_b is less than normal resulting in gas generator fuel flow less than normal. Duct heater fuel flow is less than normal due to N_2 reduction.	Gas Generator fuel flow, EPR, T_{t7} and N_2 less than normal. Duct heater fuel flow less than normal.	F_n = 70% F_{nma}. After correction F_n = 95% F_{nma}	AF and CR	Adjustment of remote EPR control will compensate for most of the reduction in effective P_b.
			Cruise: Same as SLTO	Same as SLTO	F_N = 70% Fnma after correction F_n = 85%	Same as SLTO	Same as SLTO except EPR adjustment will compensate for approximately half of the reduction in effective P_b.
			Landing: Same as SLTO	Same as SLTO	Reduction in N_1, N_2 and fuel flow. Maximum F_n limited to SLTO conditions.	Same as SLTO	Increase PLA on affected engine to maintain F_n match with unaffected engines. Same as SLTO if maximum F_n desired.
P_b Multiplying Lever Seal Bellows. 25.2.6.3	Seals P_b bellows ambient pressure cavity from control case fuel pressure.	Leak or rupture	SLTO: Fuel leakage overboard through the P_b housing drain. Rate of fuel leakage restricted by an orifice. P_b sense system essentially not affected by fuel pressure in ambient cavity.	Overboard drain fuel leakage from P_b housing drain.	Not affected	CR	None
			Cruise: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Fuel Flow Computation System 25.2.7	A feedback force balance multiplying system that computes and controls gas generator fuel flow. Fuel flow ratio, W_f/P_b, is computed through use of the speed error signal from the speed set and acceleration limiting system. This W_f/P_b is multiplied by the P_b signal from the P_b sense system to arrive at the desired gas generator fuel flow. The system controls the gas generator throttle valve system by providing a fuel flow demand signal and receiving a fuel flow feedback signal.						

The Failure Mode Index Number for this unitized control system has been reserved in the event of future need. Parts within this system consist of a cam, springs, rollers, and various linkages which are considered to be designed with sufficient margin to preclude their breakage. It was assumed that failure of the parts within this system will not occur. Failures within other unitized control systems will affect this system and the total effect of such failures including the effect on the gas generator fuel flow computation system are presented in the analysis of the appropriate system.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Blowout Reset Piston 25.2.8.1	If duct heater airflow becomes excessive the duct nozzle system provides an activation signal to the blowout reset piston until proper duct airflow has been restored by duct nozzle correction. When activated, the blowout reset piston signals a 25 W_f/P_b decrease to the gas generator fuel flow computation system in order to minimize total engine airflow increase above normal.	a) Seizure (Nonactivated position)	SLTO: This is normal operating position. In the event of substantial excessive duct airflow, gas generator fuel reduction will not occur during duct heater shutoff and duct nozzle area correction.	In the event of substantial excessive duct airflow, the normal gas generator N_2 and fuel reduction will not occur during the airflow correction. Duct heater will be shut off and duct nozzle will close to 4.5 square feet position or less during the airflow correction.	In the event of substantial excessive duct airflow correction F_n = 65% F_{nma}. After restoring augmentation F_n = 100% F_{nma}.	CR	In the event of substantial excessive duct airflow, reduce PLA to non-augmented range and then advance PLA to restore desired F_n level.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except prior to restoring augmentation F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired and failure occurs, same as SLTO	Not applicable	Not applicable If maximum F_n desired and failure occurs, same as SLTO	Not applicable	Not applicable If maximum F_n desired and failure occurs, same as SLTO
	The necessity for this reset piston has not been firmly established. Initial hardware design has provision for its incorporation. The analysis of this system is presented in the event of its incorporation and thrust levels with this reset is presented within this section only. This section also assumes the duct blowout system is incorporated. The analysis of all other section assumes the reset provision is not incorporated.	b) Seizure (activated position)	SLTO: A substantial excessive duct airflow condition must first occur to permit this seizure position. If this dual happening occurs, the gas generator fuel flow reduction during duct heater shutoff and duct nozzle area correction will remain active after the correction.	If the dual events occur, N_2 T_{t7} EPR and gas generator fuel flow will be lower than normal. Duct heater will shut off during duct nozzle correction.	If the dual events occur, F_n = 40% F_{nma} After restoring augmentation F_n = 60% F_{nma}	If the dual events occur, AF and CR	If the dual events occur, reduce PLA to nonaugmented range and then advance PLA to restore augmentation. Adjust F_n level on unaffected engines to obtain desired aircraft conditions. Adjustment of remote EPR control will restore most of fuel flow reduction.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired and dual events occur, same as SLTO	Not applicable	Not applicable. If maximum F_n desired and dual events occur, same as SLTO	Not applicable	Not applicable. If maximum F_n desired and dual events occur, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Fuel Inlet Filter 25.2.9	Contamination protection. All fuel entering the gas generator system is passed through a 20 mesh strainer. After passing through the strainer, servo fuel is passed through a 40 micronic wash type filter. The velocity of the fuel is increased past the servo filter to minimize collected contaminant on the filter. A relieving bypass valve is provided for the servo filter.	Excessive contaminant deposited on servo filter.	SLTO: When fuel pressure drop across the servo filter exceeds a preset level, the servo filter bypass valve opens allowing strained inlet fuel to bypass the servo filter. Contaminant may enter the control servo system. Dependent on the size and amount of contaminant, failures may occur in the control servo system.	Excessive contaminant in the filter and corrective action can be controlled in most instances by normal periodic inspection and maintenance.	No immediate effect.	No immediate effect.	None
			Cruise: Same as SLTO	Same as SLTO	No immediate effect.	No immediate effect.	None
			Landing: Same as SLTO	Same as SLTO	No immediate effect.	No immediate effect.	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Throttle Valve System 25.2.10.	Gas generator fuel flow metering system. The fuel flow computation system controls the positioning of the throttle valve and the throttle valve pressure regulating system controls the fuel differential pressure across the throttle valve so that throttle valve position is a direct metered fuel flow function.						
Gas Generator Throttle Valve Pilot Valve 25.2.10.1	Positions the throttle valve by modulating throttle valve servo pressure in response to the fuel flow demand signal from the fuel flow computation system.	a) Seizure in decrease metered fuel flow side of null.	SLTO: The gas generator throttle valve is scheduled to minimum fuel flow position.	Decrease in gas generator fuel flow to minimum flow. Engine dies out.	Engine dies out	IFS and CR	Move SOL to off position. Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO in addition, duct nozzle to wide open position during augmentation and to 4.5 square feet or less during non-augmentation.	N_2, T_{T7}, EPR lower than normal. Gas generator fuel flow at minimum value.	During augmentation F_N = 40% F_{nma}	AF and CR	Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
				On descent engine will die out.	On descent engine will die out.	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
		b) Seizure in increased metered fuel flow side of null.	SLTO: Gas generator fuel flow is scheduled to maximum fuel flow position.	N_2, T_{T7}, EPR and gas generator fuel flow increase	N_1, N_2, T_{T7}, EPR and gas generator fuel flow increase. Crew action is required.	IFS and CR	Move SOL to off position. Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Throttle Valve 25.2.10.2	Gas generator fuel flow metering valve.	Seizure	SLTO: Gas generator fuel flow remains at level scheduled at time of failure.	No immediate effect	No immediate effect	No immediate effect	None
				On climb after SLTO, gas generator fuel flow will remain constant instead of following normal scheduling. EPR, T_{T7} and N_2 will constantly increase above normal as altitude is increased.	EPR, N_1, N_2, and T_{T7} will constantly increase above normal as altitude is increased.	When necessary IFS. CR	When necessary to prevent exceeding engine limits, move SOL to off position. Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	None until power schedule is changed.	No immediate effect	No immediate effect	None
				Dependent on the setting at time of failure, the power schedule change results in the following:	If failure occurs at extremely low fuel flow, engine may die out on descent.	If engine dies on descent. IFS CR	If engine dies on descent, same as SLTO climb.
				A power schedule change requiring a lower fuel flow than the fuel flow at time of failure results in EPR, T_{T7}, and N_2 higher than normal.	EPR, N_1, N_2 and T_{T7} will increase above normal. Amount of deviation from normal dependent upon amount of fuel flow error at the selected setting.	Same as SLTO climb	Same as SLTO climb
				A power schedule change requiring a higher fuel flow than the fuel flow at time of failure results in EPR, T_{T7}, and N_2 lower than normal. Duct heater may be shut off if N_2 decreases by an appreciable amount due to fuel flow being too low for conditions.	EPR, N_1, N_2, and T_{T7} will decrease below normal. Amount of deviation from normal dependent upon amount of fuel flow error at the selected setting.	AF	Adjust F_N level on unaffected engines to obtain desired aircraft conditions.
			Landing: Same as Cruise	Same as Cruise	Same as Cruise	Same as Cruise	Same as Cruise

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Throttle Valve Pressure Regulating System 25.2.11	Regulates throttle valve differential pressure to a constant value so that throttle valve position is proportional to metered fuel flow.						
Pressure Regulating Valve Sensor 25.2.11.1 or Pressure Regulating Valve Integral Piston 25.2.11.2	Modulates pressure regulating valve integral piston pressure in response to sensed throttle valve differential pressure. Provides integral regulation function to pressure regulating valve spring for improved regulation by minimizing spring rate effect on pressure regulating valve position.	a) Sensor seizure in position from null to increase throttle valve differential pressure. Piston seizure in full authority position for increase in throttle valve differential pressure.	SLTO: Pressure regulating valve integral piston at full authority position for increase in throttle valve differential pressure. Throttle valve differential pressure regulation will be maintained by the proportional pressure regulating valve at a level approximately 10% higher than normal. Approximate 5% increase in metered fuel flow.	Approximately 5% increase in gas generator fuel flow. N_2, T_{t7}, and EPR higher than normal.	F_n = 105% F_{nma}	CR	Adjust remote EPR control to correct for gas generator fuel flow increase.
			Cruise: Same as SLTO except throttle valve differential pressure increased approximately 17% and approximately 8% increase in metered fuel flow.	Same as SLTO, except approximately 8% increase in gas generator fuel flow.	F_n = 105% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Reduce PLA to correct for gas generator fuel flow increase. If maximum F_n desired, same as SLTO.
		b) Sensor seizure in position from null to decrease throttle valve differential pressure. or Piston seizure in full authority position for decrease in throttle valve differential pressure.	SLTO: Pressure regulating valve integral piston at full authority position for decrease in throttle valve differential pressure. Throttle valve differential pressure regulation will be maintained by the proportional pressure regulating valve at a level approximately 10% lower than normal. Approximately 5% decrease in metered fuel flow.	Approximately 5% decrease in gas generator fuel flow. N_2, T_{t7}, and EPR lower than normal.	F_n = 95% F_{nma}	AF and CR	Adjust remote EPR control to correct for gas generator fuel flow decrease.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
			Cruise: Same as SLTO except throttle valve differential pressure decreased approximately 3%. Approximately 2% decrease in metered fuel flow. During descent fuel flow error will increase and approach SLTO percentage error.	Approximately 2% decrease in gas generator fuel flow.	Essentially not affected.	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Increase PLA to correct for gas generator fuel flow decrease. If maximum F_n desired, same as SLTO.
Pressure Regulating Valve 25.2.11.3	Regulates throttle valve differential pressure by bypassing gas generator inlet fuel flow to gas generator pump interstage.	Seizure	SLTO: Gas generator fuel flow remains essentially unchanged at time of failure although it may tend to fluctuate. As conditions change from those at time of failure, effect will be as follows:	Gas generator fuel flow may tend to fluctuate.	No immediate effect.	No immediate effect.	None
			Scheduled throttle valve increased fuel flow positioning, and/or N_2 decrease will result in gas generator fuel flow being less than normal with the amount of decrease dependent on the amount of change from conditions existing at time of failure.	Gas generator fuel flow, N_2, T_{t7}, and EPR lower than normal with reduction dependent on the amount of change from conditions existing at time of failure.	Gas generator fuel flow, N_1, N_2, and EPR lower than normal with the amount of decrease dependent on the amount of change from conditions existing at time of failure.	AF and CR	Engine power may be increased by adjustment of remote EPR control and PLA.
			Scheduled throttle valve, decreased fuel flow positioning and/or N_2 increase will result in gas generator fuel flow being higher than normal with the amount of increase dependent on the amount of change from conditions existing at time of failure.	Gas generator fuel flow, N_2, and EPR higher than normal with increase dependent on the amount of change from conditions existing at time of failure.	Gas generator fuel flow, N_1, N_2, and EPR higher than normal with the amount of increase dependent on the amount of change from conditions existing at time of failure.	CR	Engine conditions may be maintained by decreasing gas generator fuel flow with the EPR control. If engine limits cannot be maintained, reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Pressure Regulating Valve Metered Pressure Signal Damping Orifice 25.2.11.4	Dampens metered pressure signal for gas generator fuel flow stability.	Orifice plugs.	SLTO: Fuel pressure on metered signal side of pressure regulating valve will tend to follow integral piston modulated pressure. Throttle valve differential pressure will tend to oscillate approximately ± 10% from normal. Gas generator fuel flow will tend to oscillate approximately ± 5% from normal.	Gas generator fuel flow will tend to oscillate approximately ± 5% from normal. N_2 and EPR will tend to follow fuel flow oscillations.	Gas generator fuel flow will tend to oscillate approximately ± 5% from normal. N_1, N_2, and EPR will tend to follow fuel flow oscillations.	CR	After SLTO, if oscillations are objectionable, reduction of PLA below maximum non-augmented will minimize the magnitude of the oscillations.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTC	Same as SLTO	Same as SLTO	Same as SLTO
Windmill Orifice 25.2.11.6	Provide restriction for throttle valve metered fuel flow ported to case during windmill operation (IFS)	Orifice plugs.	SLTO: Not applicable. This flow path not utilized during normal engine operation.	Not applicable.	Not applicable.	Not applicable.	None
or Windmill Check Valve 25.2.11.5	One way check valve to permit throttle valve metered fuel flow to case during windmill operation only (IFS).	Seizure	In the event of positioning the SOL to the off position (IFS), flow path for throttle valve metered fuel to case is blocked. The pressure regulating valve will be positioned to full closed. Gas generator fuel pressure increase resulting in gas generator fuel pump relief valve opening.	During windmill operation at high T_{t2} values, engine oil temperature will increase.	During windmill operation at high T_{t2} values, engine oil temperature will increase and may exceed limits due to gas generator fuel flow for oil cooling reduced to only servo flow.	CR	During windmill operation, monitor engine oil temperature. If necessary to maintain engine oil temperature limits, reduce aircraft to subsonic conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Minimum Pressure and Shutoff Valve [illegible]	Maintains a minimum pressure level in the control to assure proper servo operations. This valve is also used to shut off and initiate gas generator fuel flow as signaled by the SOL sequencing valve.	Seizure	SLTO: Gas generator fuel system essentially unchanged for conditions existing at time of failure. Condition changes will result in the following:	No immediate effect.	No immediate effect.	No immediate effect	None
			Scheduled gas generator fuel flow reduction from that existing at time of failure will result in gas generator fuel system and control servo system pressures lower than normal. If fuel flow is decreased substantially from that at time of failure, may have slow wandering of gas generator fuel flow, N_2, and duct nozzle.	If gas generator fuel flow demand is decreased substantially from that at time of failure, may have slow wandering of gas generator fuel flow, N_2, T_{t7}, EPR, and duct nozzle.	If gas generator fuel flow demand is decreased substantially from that at time of failure, may have slow wandering of gas generator fuel flow, N_1, N_2, EPR, and duct nozzle.	CR	If wander occurs, increase gas generator fuel flow if possible to reduce the slow wander.
			Scheduled gas generator fuel flow increased from that existing at time of failure will result in gas generator fuel system pressure increase, if fuel flow is increased substantially from that at time of failure, fuel system pressure may increase to gas generator fuel pump pressure relief valve opening level.	If gas generator fuel flow demand is increased substantially from that at time of failure, gas generator fuel flow may be limited to less than desired. N_2, T_{t7}, and EPR will then also be less than desired.	If gas generator fuel flow demand is increased substantially from that at time of failure, gas generator fuel flow, N_1, N_2, T_{t7}, EPR may be limited to less than desired.	CR and possibly AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Engine Total Airflow Computing System 25.2.13	Engine total airflow is controlled by comparing actual duct airflow to desired duct airflow calculated from actual gas generator conditions to provide a signal to the duct airflow schedule system.						
Sensed Duct Airflow Servo Pilot Valve 25.2.13.4 or Proportional Valve 25.2.13.6	Positions sensed duct airflow servo piston in response from the sensed duct airflow computing linkage. Provides immediate transmittal to the airflow scheduled system a portion of the signal proportional to the difference between desired and sensed duct airflow. Also controls the positioning of the integral system.	Seizure in low sensed duct airflow side of null. Seizure in low sensed duct airflow side of null.	SLTO: Sensed duct airflow end of comparative linkage maintained at low sensed duct airflow position. Signal to the duct airflow schedule system to increase duct airflow. Duct nozzle area larger than normal at all augmented PLA positions and at nonaugmented PLA positions is essentially at 4.5 square feet. At maximum augmentation the duct nozzle is wide open.	Engine total airflow higher than normal. Duct nozzle area larger than normal and will be wide open at maximum augmentation.	F_n = 90% F_{nma}.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 85% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
P_{t3} Bellows Assembly 25.2.13.2 or Sensed Duct Airflow Servo Pilot Valve 25.2.13.4 or	Provides sensed P_{t3} absolute pressure signal to the sensed duct airflow computing linkage. See previous description.	Loss of dampening fluid into evacuated chamber. Seizure in high sensed duct airflow side of null.	SLTO: Sensed duct airflow end of comparative linkage maintained at high sensed duct airflow position. Signal to the duct airflow schedule system to decrease duct airflow. Duct nozzle area smaller than normal at all augmented PLA positions and full closed at nonaugmented PLA positions.	Engine surge at all augmented levels above minimum augmentation.	Engine surge at all augmented levels above minimum augmentation. After correction and at maximum nonaugmented: F_n = 65% F_{nma}.	AF and CR	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
Proportional Valve 25.2.13.6	See previous description.	Seizure in high sensed duct airflow side of null.	Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Duct nozzle area to full closed.	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
P_{t3}-P_{s3} Diaphragm and Bellows Assembly 25.2.13.1 or	Provides sensed P_{t3}-P_{s3} signal to the sensed duct airflow computing linkage.	Loss of dampening fluid into P_{t3} or P_{s3} cavities.	SLTO: Lose damping of P_{t3}-P_{s3} diaphragm and bellows assembly and P_{t3} bellows assembly.	None	Not affected. This failure results in shortening the life of the P_{t3}-P_{s3} diaphragm and bellows assembly and the P_{t3} bellows assembly.	Not affected	None
Volume Compensator Bellows 25.2.13.3 or	Temperature compensator for dampening fluid sections of P_{t3}-P_{s3} diaphragm and bellows assembly and P_{t3} bellows assembly.	Loss of dampening fluid into P_{t3} cavity.	Cruise: Same as SLTO	None	Same as SLTO	Not affected	None
			Landing: Same as SLTO	None	Same as SLTO	Not affected	None
P_{t3} Bellows Assembly 25.2.13.2	See previous description.	Loss of dampening fluid into P_{t3} cavity.					
Sensed Duct Airflow Servo Piston 25.2.13.5	Provides sensed duct airflow position signal to the comparative linkage.	Seizure	SLTO: The sensed duct airflow end of comparative linkage will be maintained in a fixed position. As conditions change the desired duct airflow end of the comparative linkage will be repositioned resulting in the following:				
			As desired duct airflow increases, the signal to the duct airflow schedule system requests an increase in duct airflow. Duct nozzle area larger than normal at all augmented PLA positions. Nonaugmented position is essentially at 4.5 square feet. At maximum augmentation the duct nozzle is wide open.	Engine total airflow higher than normal. Duct nozzle area larger than normal and will be wide open at maximum augmentation.	F_n = 90% F_{nna}.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			As desired duct airflow decreases the signal to the duct airflow schedule system requests a decrease in duct airflow. Duct nozzle area is smaller than normal at all augmented PLA positions and full closed at nonaugmented PLA conditions.	Engine surge at all augmented levels above minimum augmentation.	Engine surge at all augmented levels above minimum augmentation. After correction and at maximum nonaugmented: F_n = 65% F_{nna}.	AF and CR	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Sensed Duct Airflow Servo Piston 25.2.13.5 (Continued)			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except for nozzle area increase: F_n = 85% F_{nma}. For nozzle area decrease: F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	None for increased nozzle area.	Not affected	Not affected	None
				For decreased nozzle area, duct nozzle to full closed.	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
Integral Piston 25.2.13.7	Provides integral transmittal to the airflow schedule system of the signaled difference between desired and sensed duct airflow until this difference is reduced to zero.	Seizure	SLTO: No immediate effect while conditions remain essentially the same as those at time of failure.	None	No immediate effect.	No immediate effect.	None
			As conditions change desiring a change in airflow, only the proportional portion of the signaled difference between desired and sensed duct airflow will be transmitted to the airflow schedule system.				
			For signaled difference requesting a decrease in airflow, the duct nozzle area will be larger than normal with amount dependent on seized position of piston relative to normal integrated position for new conditions.	Engine total airflow higher than normal. Duct nozzle area larger than normal.	Same F_n reduction with F_n loss dependent upon seized position of piston relative to normal integrated position for new conditions.	CR and possibly AF.	If necessary, adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			For signaled difference requesting an increase in airflow, the duct nozzle area will be smaller than normal with amount dependent on seized position of piston relative to normal integrated position for new conditions.	Engine total airflow lower than normal. Duct nozzle area is smaller than normal. Engine may surge at some conditions.	Engine may surge at some conditions dependent upon seized position of piston relative to normal integrated position for new conditions.	CR and possibly AF	If engine surges, reduce to and/or maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Airflow Schedule System 25.2.14	Schedules duct airflow as signaled by the difference between desired and sensed duct airflow from the engine total airflow computing system, and by augmentation level from the duct heater scheduling and fuel flow computation system.						
Area Control Valve Flapper Valve 25.2.14.1	Modulates area control valve servo pressure to control duct airflow by duct nozzle area positioning.	Contaminant, valve fails in open position.	SLTO: Duct nozzle scheduled to wide open position	Engine total airflow higher than normal duct nozzle area to wide open position.	F_n = 90% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 85% F_{nma}	Same as SLTO	Same as SLTO
or			Landing: Same as SLTO	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
Area Control Valve Modulated Pressure Supply Orifice 25.2.14.2	Permits modulation of area control valve servo pressure.	Plugged					
or Area Control Valve 25.2.14.3	Positions duct nozzle area to control duct airflow.	Seizure in increase duct area side of null.					

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Area Control Flapper Valve 25.2.14.1 or	See previous description	C- aminant, valve fails in closed position.	SLTO: Duct nozzle scheduled to full closed position.	Engine surge at all augmented levels above minimum augmentation. Duct nozzle to full closed position.	Engine surge at all augmented levels above minimum augmentation. After correction and at maximum nonaugmented F_n = 65% F_{nma}.	AF and CR	Reduce to and maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
Area Control Valve 25.2.14.3 or	See previous description	Seizure in decrease duct area side of null.	Cruise: Same as SLTO	Same as SLTO	Same as SLTO except F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Duct Nozzle to full closed position.	Not affected If maximum F_n desired, same as SLTO	Not affected	None If maximum F_n desired, same as SLTO.
Area Control Valve Regulated Pressure Damping Orifice 25.2.14.4	Dampens regulated pressure to high pressure side of area control valve.	Plugged					

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Maximum Area Stop 25.2.15.1	Limits duct nozzle area to a maximum of 4.5 square feet at all non-augmented conditions. The stop is activated to either its limiting position or withdrawn as a function of Zone I manifold fuel level and ignition valve position.	Seizure in withdrawn position	SLTO: Not affected during augmentation and non-augmented PLA range above approximately 90% N_2.	None	Not affected	Not affected	None
			At non-augmented PLA range below approximately 90% N_2, the duct nozzle area will be somewhat larger than normal.	At nonaugmented PLA range below approximately 90% N_2 the duct nozzle will be somewhat larger than the normal 4.5 square feet.	F_n will be somewhat lower than normal	CR	Adjust F_n level on affected engine to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
		Seizure in limiting position	SLTO: Not applicable for initial augmentation condition.	Not applicable	Not applicable	Not applicable	None
			If duct heater shutoff and failure occurs, duct nozzle area lower than normal on subsequent augmentation.	Duct nozzle area lower than normal on subsequent augmentation. Engine may surge during augmentation.	Engine may surge during augmentation. If engine surge occurs, alter correction and at maximum nonaugmented $F_n = 65\%\ F_{nma}$.	AF and CR	If engine surges during augmentation, reduce to and/or maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except $F_n = 20\%\ F_{nma}$	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO duct heater shutoff.	None	Not affected. If maximum F_n desired, same as SLTO duct heater shutoff.	Not affected	None. If maximum F_n desired, same as SLTO duct heater shutoff.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Nozzle Feedback Failsafe Valve 25.2.16.1	Provides signal to duct heater blowout valve to shut off duct heater in the event that duct nozzle feedback signal is lost. The necessity for the duct heater blowout system has not been firmly established. The use of the duct nozzle feedback failsafe valve is directly related to the use of the duct heater blowout system. Initial hardware design has provision for incorporation of both systems. The analysis of these systems is presented in the event of their incorporation. The analysis of all other sections with the exception of the duct heater blowout reset piston assumes the duct heater feedback failsafe valve and duct heater blowout valve are not incorporated.	Seizure in non shut-off position	Not affected unless the duct nozzle feedback signal is lost.	None	Not affected	Not affected	None
			SLTO: In the event the duct nozzle feedback signal is lost (double failure), there is no signal to the duct heater blowout valve to shut off the duct heater if on, or prevent initiation if off. For this failure condition, the loss of duct nozzle feedback results in the duct nozzle going to wide open position.	Nozzle to wide open position.	$F_n = 95\% F_{nma}$	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	$F_n = 85\% F_{nma}$	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO	Not affected	None. If maximum F_n desired, same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Blowout System 25.2.17	Shuts off the duct heater in the event of loss of duct nozzle feedback or in the event of substantial excessive duct airflow.	a) Seizure of piston or valve in position to permit duct heater operation or signal orifice plugged.	SLTO: In the event of substantial excessive duct airflow, the duct heater will not be shut off if on or can be initiated if off. The highest excessive duct airflow condition is for a nozzle wide open failure which could be caused by the loss of the duct nozzle feedback.	For duct nozzle wide open failure, The duct heater is not shut off if on or can be initiated if off.	F_n = 90% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
consisting of			Cruise: Same as SLTO	Same as SLTO	F_n = 85% F_{nma}	Same as SLTO	Same as SLTO
Duct Heater Blowout Valve 25.2.17.1 and Duct Heater Blowout Valve Piston 25.2.17.2 and Signal Orifice 25.2.17.3	The necessity for the duct heater blowout system has not been firmly established. Initial hardware design has provision for its incorporation. The analysis of this system is presented in the event of its incorporation. The analysis of all other sections with the exception of the duct heater blowout reset piston and the duct nozzle feedback failsafe valve assumes the duct heater blowout system is not incorporated.		Landing: Not affected. If maximum F_n desired, same as SLTO	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO	Not affected	None. If maximum F_n desired, same as SLTO
		b) Seizure of piston or valve in position to not permit duct heater operation	SLTO: For this failure to exist, a substantial excessive duct airflow condition or loss of duct nozzle feedback must first occur. If they do occur, duct heater is shut off if on or cannot be initiated if off. The highest excessive duct airflow condition is for a duct nozzle wide open failure which could be caused by the loss of the duct nozzle feedback.	For duct nozzle wide open failure, the duct heater is shut off if on or cannot be initiated if off.	F_n = 40% F_{nma}	AF and CR	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 10% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO	Not affected	None. If maximum F_n desired, same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Schedule Pilot Valve and Servo System 25.2.18	Positions duct heater scheduling cam as a function of PLA.						
Duct Schedule Pilot Valve 25.2.18.1	Modulates servo-pressure to duct schedule servo piston to position the servo-piston as a function of PLA.	Seizure in increase PLA side of null position.	SLTO: Duct schedule cam positioned to maximum augmentation PLA position. Duct heater fuel flow will remain at maximum PLA schedule level when PLA reduced. T_{t2} bias of duct heater schedule will continue to function. Duct heater fuel shutoff and initiation with PLA will continue to function.	Duct heater fuel flow cannot be reduced with PLA.	Duct augmentation level cannot be reduced with PLA.	CR	Engine can be operated at maximum augmentation or augmentation can be shut off. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
or Duct Schedule Servo Piston 25.2.18.2	Translates duct schedule cam as controlled by the duct schedule pilot valve so that the schedule cam is positioned as a function of PLA.	Seizure in maximum PLA position.	For duct heater shutoff, normal reduction to duct heater circulation fuel flow will continue to function for pilot valve seizure. Circulation fuel flow will be of maximum augmentor PLA level for servo piston seizure.	For servo piston seizure, duct heater circulation fuel flow will be at maximum augmentation PLA level.	Not affected. System can handle this level of circulation fuel flow.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
Duct Schedule Pilot Valve 25.2.18.1	See previous description	Seizure in decrease PLA side of null position.	SLTO: Duct schedule cam positioned to circulating flow position. Duct heater fuel flow scheduled at minimum ratio at all augmented PLA positions. Duct heater fuel shut off and initiation with PLA will continue to function.	Duct heater fuel flow at minimum ratio values at all augmented PLA positions.	F_n = 65% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
or Duct Schedule Servo Piston 25.2.18.2	See previous description	Seizure in nonaugmentation PLA position.	Cruise: Same as SLTO	Same as SLTO	F_n = 25% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected.	None. If maximum F_n desired, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Schedule Servo Piston 25.2.18.2	See previous description	Seizure in any position between minimum and maximum PLA positions.	SLTO: Duct heater fuel flow remains at PLA schedule existing at time of failure. T_{t2} bias of duct heater schedule will continue to function. Duct heater fuel shutoff and initiation with PLA will continue to function.	Duct heater fuel flow cannot be modulated with PLA.	Duct heater fuel flow cannot be modulated with PLA. F_n level will be between the two extremes previously described with level dependent on failure position.	CR If failure occurs at low augmented PLA position, AF.	Engine can be operated at existing augmented level or augmentation can be shut off. Adjust F_n level on unaffected engines to obtain desired aircraft condition.
			For duct heater shutoff, circulation flow will remain at augmented schedule existing at time of failure.	For duct heater shutoff, circulation flow will remain at augmented schedule existing at time of failure and will vary with T_{t2}.	Not affected. System can handle level of circulation fuel flow.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
Duct Schedule Servo Rate Pilot Valve 25.2.18.3	Varies the response rate of the duct PLA fuel flow schedule as a function of T_{t2}.	Seizure	SLTO: Duct PLA fuel flow schedule response rate remains at conditions existing at time of failure. There is no effect on response rate until T_{t2} increased above approximately 200°F followed by a reduction in T_{t2}.	No immediate effect.	No immediate effect.	No immediate effect.	None
			Cruise: Same as SLTO. Pilot valve will continue to be driven in an increasing T_{t2} direction with normal response rate maintained.	No immediate effect.	No immediate effect.	No immediate effect.	None
			When T_{t2} increased above approximately 200°F, subsequent operation at T_{t2} values less than highest T_{t2} value encountered will result in duct heater fuel flow PLA response rate being less than normal with rate dependent on highest T_{t2} encountered.	When T_{t2} increased above approximately 200°F, lower than normal duct heater fuel flow PLA response rate at T_{t2} values less than highest T_{t2} value encountered.	Minor reduction in duct heater fuel flow PLA response rate at T_{t2} values less than highest T_{t2} value encountered where highest T_{t2} value has exceeded approximately 200°F.	CR	None
			Landing: Not affected	Not affected	Not affected	Not affected	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Low Speed Protection Valve 25.2.19.1	Protects against duct heater initiation below a predetermined N_2 speed. Also protects against reverser-suppressor actuation above a predetermined N_2 speed.	a. Seizure at or above approximately 90% N_2 position.	SLTO: This is normal position during augmentation.	None	Not affected	Not affected	None
			Speed protection authority lost. Duct heater can be initiated with PLA at any N_2 speed.	Duct heater initiation with rapid PLA augmentation positioning while engine at a low N_2 speed.	Duct heater initiation with rapid PLA movement from a low nonaugmented setting may result in engine surge.	CR If engine surges, may have IFS.	If engine surges, retard PLA to idle then advance PLA into augmented range only when N_2 is above approximately 80%.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO. Also, reverser-suppressor cannot be activated.	Same as SLTO. Also, reverser-suppressor cannot be actuated.	Not affected. Reverser-suppressor cannot be activated.	Same as SLTO	If reverse desired, reduce PLA to idle and adjust reverse F_n level on unaffected engines.
		b. Seizures in any other position than (a) above.	For seizures in any other position than (a) above, an increase in speed above 90% N_2 will drive the low speed protection valve to the position described above and the effects will be the same. If the seizure occurs at less than approximately 90% N_2 and speed is not increased above this value, the reverser-suppressor actuation with PLA is not affected.				

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Sequence, Fill and Dump System 25.2.20	This system provides a limit on metered fuel flow during filling of either Zone I or Zone II manifolds until manifold filling has been accomplished. Energizing of duct heater electrical ignition is scheduled during Zone I manifold filling. Rapid manifold fill systems are scheduled for both of the manifold systems. A bias is provided to the total airflow control system to minimize the airflow transient during initiation of burning in either of the zone systems. Signals are provided for draining of each manifold upon shutoff of the applicable zone. Circulation of duct heater fuel flow to gas generator fuel pump interstage is provided upon Zone I shutoff.						
Duct Heater Fill, Shutoff, and Dump Control Valve 25.2.20.1 or Duct Heater Fill, Shutoff, and Dump Control Valve Piston 25.2.20.2	Positioned by PLA when authorized by N_2 speed level to a) Energize electrical ignition igniters. b) Provides bias to total airflow control system to minimize the airflow transient upon Zone I initiation. c) If SOL in "on" position, closes Zone I manifold dump valve and initiates zone manifold rapid fill.	a) Seizure in duct heater off position	SLTO: Not applicable during augmentation. If duct heater shut off and failure occurs, cannot reinitiate duct heater fuel flow.	Not applicable Cannot initiate augmentation.	Not applicable $F_n = 65\% F_{nma}$.	Not applicable AF and CR	None Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except $F_n = 20\% F_{nma}$.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO nonaugmented.	None	Not affected. If maximum F_n desired: $F_n = 65\% F_{nma}$.	Not affected	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Fill, Shutoff, and Dump Control Valve 25.2.20.1 or Duct Heater Fill, Shutoff, and Dump Control Valve Piston 25.2.20.2 (Continued)	d) Places the Zone II manifold fill system in PLA control upon activation of Zone I manifold fill sensor. Positions the duct heater fill, shutoff, and dump control valve in response to signals controlled by PLA when authorized by N_2 speed.	b) Seizure in duct heater on position.	SLTO: Augmentation not affected.	None	Not affected	Not affected	None
			Minimum duct heater fuel flow to Zone I at all PLA positions in nonaugmented range. Duct heater fuel flow may be shut off only with SOL.	Augmentation cannot be shut off with PLA or speed reduction below 80% N_2.	Minimum augmentation at all PLA positions in nonaugmented range.	CR	Use normal PLA schedule on affected engine. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO. In addition, minimum duct heater fuel flow during reverse operation.	Same as SLTO	Same as SLTO. In addition, minimum augmentation during reverse operation.	Same as SLTO	Same as SLTO
Zone I Shutoff Valve 25.2.20.3	Opens or closes port to Zone I manifold as signaled by duct heater fill, shutoff, and dump control valve which is controlled by PLA with authorization of SOL and N_2.	a) Seizure in closed position.	SLTO: Not applicable during augmentation.	Not applicable	Not applicable	Not applicable	None
			If duct heater shutoff and failure occurs, cannot reinitiate duct heater fuel flow.	Cannot initiate augmentation.	F_n = 65% F_{nma}	AF and CR	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
		o	Landing: Not affected. If maximum F_n desired, same as SLTO nonaugmented.	None	Not affected. If maximum F_n desired, F_n = 65% F_{nma}	Not affected	None. If maximum F_n desired, same as SLTO nonaugmented.
		b) Seizure in open position.	SLTO: Not affected during duct heater operation.	None	Not affected during duct heater operation.	Not affected	None
			When PLA reduced to nonaugmented range, duct heater circulating fuel flow plus intermittent rapid fill fuel ported to Zone I manifold with most of this fuel flowing out Zone I dump valve overboard drain.	Continuous fuel flow from Zone I dump valve overboard drain when PLA in nonaugmented range.	At nonaugmented PLA range, continuous flow of fuel from Zone I dump valve overboard drain.	CR	Maintain augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	None. If maximum F_n desired and seizure occurs, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Zone II Shutoff Valve 25.2.20.4	Opens or closes port to Zone II manifold as signaled by PLA with authorization by duct heater fill, shutoff, and dump control valve and by Zone I manifold fill sensor valve.	a. Seizure in closed position.	SLTO: Not applicable during augmentation level above zone transfer.	Not applicable	Not applicable	Not applicable	None
			If PLA reduced below zone transfer level or augmentation shutoff and failure occurs, cannot reinitiate Zone II fuel flow. Subsequent duct heater fuel flow scheduling above zone transfer level will result in all duct heater fuel flow ported to Zone I.	After seizure, duct heater fuel flow scheduling above zone transfer level may result in duct heater blow out when fuel flow is approximately 25% higher than transfer value.	After seizure essentially normal augmentation maintained up to duct heater fuel flows of approximately 25% higher than zone transfer level. Further increase in duct heater fuel flow may result in duct heater blow out. At duct heater fuel flow zone transfer: $F_n = 90\% F_{nmax}$.	AF and CR	If duct heater blows out, augmentation can be reinitiated. Maintain PLA range at zone transfer level or lower. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO reduced augmentation.	Same as SLTO	Same as SLTO except $F_n = 80\% F_{nmax}$.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO reduced augmentation.	None	Not affected. If maximum F_n desired, same as SLTO reduced augmentation.	Not affected	None. If maximum F_n desired, same as SLTO reduced augmentation.
		b. Seizure in open position.	SLTO: Not affected during augmentation level above zone transfer.	None	Not affected	Not affected	None
			If PLA reduced below zone transfer level, duct heater fuel flow or rapid fill fuel will alternately be ported to Zone II manifold with most of this fuel flowing out Zone II dump valve overboard drain. At Zone I augmented PLA range, Zone I fuel flow reduced when Zone II fuel ported overboard. Reinitiation of duct heater fuel flow after shut off, will result in slow Zone I filling.	Below zone transfer PLA level, continuous fuel flow from Zone II dump valve overboard drain. During Zone I augmented PLA range, duct nozzle, duct heater fuel flow, and F_n will tend to fluctuate. Duct heater will blow out as PLA is reduced near minimum augmentation. After duct heater is shut off, reinitiation will be slower than normal.	Normal engine operation above zone transfer PLA range. Below zone transfer PLA position, continuous fuel flow from Zone II dump valve overboard drain. During Zone I augmentation PLA range, F_n tends to fluctuate. Duct heater will blow out as augmentation is reduced to near minimum level. Reinitiation of augmentation after shut off is slower than normal.	CR	Maintain PLA above zone transfer position. Reinitiate augmentation at high PLA if duct heater blows out. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Normally not applicable since normal cruise condition is with Zone I operation only. If Zone II operated at cruise and seizure occurs, same as SLTO.	Normally not applicable. If seizure occurs, same as SLTO.	Normally not applicable. If seizure occurs, same as SLTO.	Normally not applicable. If seizure occurs, same as SLTO.	None. If seizure occurs, same as SLTO.
			Landing: Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	None. If maximum F_n desired and seizure occurs, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Zone II Rapid Fill Valve 25.2.20.5	Ports either gas generator fuel pump interstage fuel for rapid fill or duct heater metered fuel to Zone II outlet as signaled by the Zone II manifold fill sensor.	Seizure in position to port rapid fill fuel to outlet.	SLTO: Not applicable at augmentation above zone transfer level.	Not applicable	Not applicable	Not applicable	None
			If PLA reduced below zone transfer level and seizure occurs, subsequent augmentation above zone transfer will result in continuous gas generator pump interstage fuel to Zone II manifold and all duct heater fuel to Zone I manifold.	After seizure, duct heater fuel flow scheduling above zone transfer level may result in duct heater blow out when fuel flow is approximately 25% higher than transfer value.	Zone I operation not affected until duct heater fuel increased approximately 25% above zone transfer level. Further increase in duct heater fuel flow may result in duct heater blow out. At duct heater zone transfer: F_n = 90% F_{nma}.	AF and CR	If duct heater blows out, augmentation can be reinitiated. Maintain PLA range at zone transfer level or lower. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
or							
Zone II Manifold Fill Sensor Valve 25.2.20.6	Senses Zone II manifold fuel level and provides signals to control the rapid fill valve and the Zone II schedule limit valve.	Seizure in manifold drained position.					
or			Also, for seizure of Zone II manifold fill sensor valve or piston, the Zone II schedule limit value is not actuated which limits duct heater fuel flow to zone transfer level. Also duct nozzle is continuously biased for Zone II ignition anticipation position.	Duct nozzle area somewhat larger than normal. Duct heater fuel flow can not be increased with PLA above zone transfer level.	F_n = 90% F_{nma}.	Same as above	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
Zone II Manifold Fill Sensor Valve Piston 25.2.20.7	Position the Zone II manifold fill sensor valve in response to manifold fuel level.	Seizure in manifold drained position.					
			Cruise: Same as SLTO reduced augmentation.	Same as SLTO reduced augmentation.	Same as SLTO reduced augmentation except: F_n = 80% F_{nma}.	Same as SLTO reduced augmentation.	Same as SLTO reduced augmentation.
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
Zone II Rapid Fill Valve 25.2.20.5	See previous description.	Seizure in position to port duct heater metered fuel to outlet.	SLTO: No immediate effect.	None	No immediate effect.	No immediate effect.	None
			After PLA reduction below zone transfer level, will not have Zone II quick fill for subsequent operation above zone transfer PLA position. Zone I fuel reduced during Zone II filling. Also, for Zone II manifold fill sensor valve or piston seizures, the Zone II schedule limit valve remains in the nonlimiting position. On PLA positioning above zone transfer level, duct heater fuel flow will be scheduled by PLA without normal limiting for Zone II manifold filling.	After PLA reduction below zone transfer, on subsequent PLA advances above zone transfer there will be a F_n reduction and duct nozzle area decrease during Zone II manifold filling.	F_n reduction during Zone II manifold filling. Duct heater may blow out during Zone II manifold filling. Augmentation up to zone transfer level not affected. At duct heater zone transfer: F_n = 90% F_{nma}.	CR. If duct heater blows out, AF.	If duct heater blows out, augmentation can be reinitiated. Maintain PLA range at zone transfer level or lower. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
or							
Zone II Manifold Fill Sensor Valve 25.2.20.6	See previous description.	Seizure in manifold filled position.					
or							
Zone II Manifold Fill Sensor Valve Piston 25.2.20.7	See previous description.	Seizure in manifold filled position.					

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Zone II Rapid Fill Valve 25.2.20.5 or Zone II Manifold Fill Sensor Valve 25.2.20.6 or Zone II Manifold Fill Sensor Valve Piston 25.2.20.7 (Continued)			Cruise: Normally not applicable since normal cruise condition is with Zone I operation only. If Zone II operated at cruise and seizure occurs, same as SLTO.	Normally not applicable. If seizure occurs, same as SLTO.	Normally not applicable. If seizure occurs, same as SLTO except F_n = 80% F_{nma}.	Normally not applicable. If seizure occurs, same as SLTO.	None. If seizure occurs, same as SLTO.
			Landing: Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	None. If maximum F_n desired and seizure occurs, same as SLTO.
Circulation Flow Valve 25.2.20.8	As signaled by Zone I manifold fill sensor, ports gas generator pump interstage fuel to Zone I manifold for rapid fill during duct heater initiation and ports duct heater circulating fuel to gas generator pump interstage during duct heater off operation.	a. Seizure in duct heater on position.	SLTO: No immediate effect.	None	No immediate effect.	No immediate effect.	None
			When duct heater shut off, have no duct heater circulating fuel flow. Duct heater fuel pressure increases to maximum capability of duct heater fuel pump.	No duct heater circulation fuel flow when duct heater shut off.	No immediate effect. On climb with duct heater shut off, engine oil temperature will eventually increase and may exceed limits.	CR	Maintain augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			On reinitiation of duct heater, Zone I filling will be slower than normal.	Duct heater initiation slower than normal.	Duct heater initiation slower than normal.	Same as above	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	None. If maximum F_n desired and seizure occurs, same as SLTO.
		b. Seizure in circulation position.	SLTO: Not applicable during initial augmentation.	Not applicable	Not applicable	Not applicable	None
			Not affected during duct heater off conditions.	None	Not affected	Not affected	None
			Duct heater initiation after seizure will result in circulation flow path to gas generator pump interstage remaining open after rapid fill has been completed. Zone I fuel flow constant at approximately 5000 pph at all augmented PLA positions. Zone II fuel flow constant at approximately 3000 pph at all augmented PLA positions above zone transfer.	Lower than normal thrust. Essentially no change in augmentation level with PLA modulation.	F_n = 70% F_{nma}.	AF and CR.	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Circulation Flow Valve 25.2.20.8 (Continued)			Cruise: Same as SLTO	Same as SLTO	F_n = 35% F_{nma}.	Same as SLTO	Same as SLTO.
			Landing: Not affected. If maximum F_n desired, same as SLTO duct heater initiation.	None	Not affected. If maximum F_n desired, same as SLTO duct heater initiation.	Not affected	None. If maximum F_n desired, same as SLTO duct heater initiation.
Zone I Manifold Fill Sensor Valve 25.2.20.9	Senses Zone I manifold fuel level and provides signals to control the circulation flow valve and the Zone I schedule limit valve. This valve permits duct heater ignition upon augmentation initiation and de-energizes ignition after Zone I manifold is filled. Also, permits Zone II initiation with PLA only when Zone I manifold is full.	Seizure in manifold drained position.	SLTO: Not applicable during initiation of augmentation.	Not applicable	Not applicable	Not applicable	None
			Not affected during duct heater off conditions.	None	Not affected	Not affected	None
or			Duct heater initiation after seizure will result in circulation flow path to gas generator pump interstage remaining open after rapid fill has been completed. Zone I fuel flow constant at approximately 5000 pph at all augmented PLA positions. Zone II cannot be initiated. Duct heater igniters remain energized during augmentation.	Voltage signal generator will indicate duct heater igniters energized. Lower than normal F_n. No change in augmentation level with PLA modulation.	F_n = 70% F_{nma}. Continued operation at this failure condition will shorten life of duct heater igniters. If duct heater shut off: F_n = 65% F_{nma}.	AF and Ck	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions. Use augmentation for emergency only.
Zone I Manifold Fill Sensor Valve Piston 25.2.20.10	Positions the Zone I manifold fill sensor valve in response to manifold fuel level.	Seizure in manifold drained position.	Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 35% F_{nma}. If duct heater shut off: F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO initiation.	None	Not affected. If maximum F_n desired, same as SLTO initiation.	Not affected	None. If maximum F_n desired, same as SLTO initiation.
Zone I Manifold Fill Sensor Valve 25.2.20.9	See previous description.	Seizure in manifold filled position.	SLTO: No immediate effect.	None	No immediate effect.	No immediate effect.	None
or			On duct heater shutoff after failure, the circulation valve remains in the duct heater on position. Duct heater fuel pressure increases to maximum capability of duct heater fuel pump. Zone I schedule limit valve remains in the nonlimiting position. Cannot energize duct heater ignition igniters during attempted initiation of augmentation.	Zero duct heater circulation fuel flow when duct heater off. Cannot initiate augmentation after shut off due to inability to energize duct heater ignition igniters. During attempt to initiate augmentation, duct heater fuel flow scheduled by PLA position and not maintained at normal low value until Zone I manifold filled.	Cannot initiate augmentation after shutoff. F_n = 65% F_{nma}.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
Zone I Manifold Fill Sensor Valve Piston 25.2.20.10	See previous description.	Seizure in manifold filled position.			On climb with PLA in nonaugmented range, engine oil temperature will increase and may exceed limits.	Same as above.	If necessary to maintain oil temperature limit, advance PLA to minimum augmentation level.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Zone I Manifold Fill Sensor Valve 25.2.20.9 or Zone I Manifold Fill Sensor Valve Piston 25.2.20.10 (Continued)			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	Not applicable. If maximum F_n desired and seizure occurs, same as SLTO.	Not applicable	None. If maximum F_n desired and seizure occurs, same as SLTO.
Duct Heater Ignition Valve 25.2.20.11	Positions the duct heater ignition switch for energizing and de-energizing of the duct heater igniters on signal from the duct heater fill, shutoff, and dump control valve as authorized by the Zone I manifold fill sensor valve. This valve also controls signals to the Zone I schedule limit valve during initiation of augmentation.	Seizure in ignition de-energized position.	SLTO: No immediate effect.	None	No immediate effect.	No immediate effect.	None
			After duct heater shutoff, duct heater ignition system cannot be energized.	After shutoff, cannot reinitiate augmentation.	F_n = 65% F_{nma}.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO initiation.	None	Not affected. If maximum F_n desired, same as SLTO initiation.	Not affected	None. If maximum F_n desired, same as SLTO initiation.
or Duct Heater Ignition Valve Diaphragm 25.2.20.12	Positions the duct heater ignition valve in response to positioning signal.	Rupture					
Duct Heater Ignition Valve 25.2.20.11	See previous description.	Seizure in ignition energized position.	SLTO: Not applicable during initial augmentation above minimum level.	Not applicable	Not applicable	Not applicable	None
			Seizure can only occur during duct heater initiation. If this seizure occurs, duct heater fuel flow limited to minimum ratio level. Also duct heater igniters remain energized at all PLA levels.	Augmentation limited to minimum ratio level. Voltage signal generator will indicate duct heater igniters continuously energized at all PLA levels.	F_n = 65% F_{nma}. This failure condition will shorten the life of the duct heater igniters.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 25% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not applicable. If maximum F_n desired and failure occurs, same as SLTO.	Not applicable	Not applicable. If maximum F_n desired and failure occurs, same as SLTO.	Not applicable	None. If maximum F_n desired and failure occurs, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Ignition Valve Orifice 25.2.20.13	To sequence de-energizing of the duct heater igniters after augmentation fuel flow has been established.	Plugged orifice.	SLTO: No immediate effect. For duct heater initiation after failure, energizing of duct heater igniters not affected. Slower than normal deenergizing of igniters and activation of Zone I duct heater schedule limit valve with both functions dependent on leakage rate past duct heater ignition valve check valve.	No immediate effect during augmentation initiation. After failure, voltage signal generator will indicate duct heater igniters energized longer than normal. Augmentation level increase after initiation is delayed longer than normal.	No immediate effect. Augmentation initiation after failure will result in slower than normal augmentation level increase after initiation.	No immediate effect. CR	None. If augmentation increase delay is significant, adjust F_n level on unaffected engines until desired augmentation obtained on affected engine.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO initiation.	None	Not affected. If maximum F_n desired, same as SLTO initiation.	Not affected	None. If maximum F_n desired, same as SLTO initiation.
Duct Heater Ignition Valve Check Valve 25.2.20.14	Provides rapid translation of duct heater ignition valve in duct heater igniters energizing direction and to permit slower translation in de-energizing direction.	Seizure in open position.	SLTO: Not applicable during initial augmentation.	Not applicable	Not applicable	Not applicable	None
			Failure can occur only during duct heater initiation. If this failure occurs, duct heater ignition valve translation in duct heater igniters de-energized direction will be faster than normal.	Augmentation initiation after failure may result in inability to establish augmentation.	After failure may not be able to ignite duct heater fuel. If cannot establish augmentation: F_n = 65% F_{nma}.	CR. If augmentation cannot be established, AF.	If augmentation cannot be established, adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO initiation.	None	Not affected. If maximum F_n desired, same as SLTO initiation.	Not affected	None. If maximum F_n desired, same as SLTO initiation.
Duct Heater Ignition Switch 25.2.20.15	On-off switch to energize or deenergize duct heater igniters.	a. Failure in energized position.	SLTO: Not affected.	Voltage signal generator will indicate continuous duct heater igniter energization.	Not affected. This failure will shorten the life of the duct heater igniters.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
		b. Failure in deenergized position.	SLTO: No immediate effect.	No immediate effect.	No immediate effect.	No immediate effect.	None
			After failure, energizing of duct heater igniters can not be accomplished during augmentation initiation.	If duct heater shut off after failure, augmentation cannot be reestablished.	If duct heater shut off after failure, duct heater fuel cannot be ignited on subsequent augmentation initiation: F_n = 65% F_{nma}.	AF and CR	If duct heater shut off after failure, adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except: F_n = 20% F_{nma}.		Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO initiation.	None	Not affected. If maximum F_n desired, same as SLTO initiation.	Not affected	None. If maximum F_n desired, same as SLTO initiation.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Zone I Schedule Limit Valve 25.2.20.16	To limit Zone I fuel flow level until the Zone I manifold is full and the duct igniter has been de-energized, to shut off PLA activated airflow bias signal which increased total engine airflow during augmentation initiation in anticipation of augmentation.	a. Seized in low fuel flow position.	SLTO: Not applicable during initial augmentation above minimum level.	Not applicable	Not applicable	Not applicable	None
			For duct heater initiation after failure, duct heater fuel flow will be maintained at minimum ratio level. Total airflow bias remains in effect during augmentation.	Augmentation limited to minimum ratio level.	F_n = 65% F_{nma}. Some increase in total engine airflow.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 25% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO initiation.	None	Not affected. If maximum F_n desired, same as SLTO initiation.	Not affected	None. If maximum F_n desired, same as SLTO initiation.
		b. Seizure in non-limiting position.	SLTO: No immediate effect. On duct heater initiation after failure, duct heater fuel flow will not be limited to minimum level during initiation. PLA activated total airflow bias signal will not be present during augmentation initiation.	None. None if minimum augmentation PLA used at initiation. If higher PLA used for initiation, duct heater may blow out.	No immediate effect. Duct heater may blow out upon initiation if high augmentation PLA used.	No immediate effect. CR	None. Use minimum augmentation PLA position for initiation.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not applicable	Not applicable	Not applicable	Not applicable	None
Zone II Schedule Limit Valve 25.2.20.17	To limit Zone II fuel flow level until the Zone II manifold is full. To shut off PLA airflow bias signal which increased total engine airflow during zone transfer in anticipation of transfer.	a. Seized in low fuel flow position.	SLTO: Not applicable during initial augmentation above zone transfer.	Not applicable	Not applicable	Not applicable	None
			For zone transfer initiation after failure, duct heater fuel flow will be maintained at the transfer ratio value. Total airflow bias remains in effect during Zone II level of augmentation.	Augmentation limited to transfer ratio level.	F_n = 90% F_{nma}. Some increase in total engine airflow.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Normally not applicable since normal cruise condition is with Zone I operation only. If Zone II operated at cruise and seizure occurs, same as SLTO.	Normally not applicable. If seizure occurs, same as SLTO.	Normally not applicable. If seizure occurs, F_n = 80% F_{nma}. Some increase in total engine airflow.	Normally not applicable. If seizure occurs, same as SLTO.	None. If seizure occurs, same as SLTO.
			Landing: Not affected. If maximum F_n desired, same as SLTO initiation.	None	Not affected. If maximum F_n desired, same as SLTO initiation.	Not affected	None. If maximum F_n desired, same as SLTO initiation.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Zone II Schedule Limit Valve 25.2.20.17 (Continued)		b. Seizure in non-limiting position.	SLTO: No immediate effect. On duct heater initiation after failure, Zone II fuel flow will not be limited to transfer ratio during transfer. PLA airflow bias signal will not be present during zone transfer.	None. None if minimum transfer PLA used at transfer. If higher PLA used for transfer Zone II may blow out.	No immediate effect. Zone II may blow out upon initiation if high Zone II PLA used.	No immediate effect. CR	None. Use minimum PLA position for transfer.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not applicable	Not applicable	Not applicable	Not applicable	None
Total Engine Airflow Bias Signal Selector Valve 25.2.20.18	Total engine airflow bias signals for duct heater fuel schedule transients are utilized during the transient and can originate from the duct schedule valve during large rapid PLA transients or from PLA positioning for augmentation initiation and for zone transfer. This selector valve is positioned to pass an airflow bias signal from either source and block the nonsignaling port whenever a bias signal is present.	a. Seizure in position to pass only the bias signal from the duct schedule valve.	SLTO: Rapid PLA transients during augmentation not affected.	None	Not affected	Not affected	None
			During initiation of duct heater fuel flow or initiation of zone transfer, the airflow bias signal will not be passed to the total airflow reset piston.	Normal engine total airflow increase during augmentation initiation or zone transfer will not occur.	Engine not appreciably affected.	CR	If desired, use minimum PLA positions for initiating augmentation and zone transfer to minimize these transients.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
		b. Seizure in position to pass only the bias signal from PLA positioning for duct heater initiation or zone transfer.	SLTO: Initiation of duct heater fuel flow or zone transfer not affected.	None	Not affected	Not affected	None
			During large rapid PLA transients in augmented range, the airflow bias signal will not be passed to the total airflow reset piston.	Normal engine total airflow increase during large rapid augmented PLA transients will not occur.	Engine not appreciably affected.	CR	If desired, use slow PLA movements in augmented range to minimize this transient.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
Total Engine Airflow Bias Reset Piston Check Valve 25.2.20.19	Provides rapid translation of engine total airflow reset piston in reset direction and to permit slower translation to remove the reset.	Seizure in open position.	SLTO: Translation of airflow reset piston in reset direction not affected.	None	Not affected	Not affected	None
			Translation of airflow reset piston to remove reset will be faster than normal.	Removal of total airflow bias will be faster than normal after large rapid PLA augmentation transients, initiation of augmentation and zone transfer.	Engine not appreciably affected.	CR	If desired to minimize transients, use minimum PLA positions for initiation of augmentation and zone transfer. Also use slow PLA augmentation transients.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Total Engine Airflow Bias Reset Piston Check Valve 25.2.20.19 (Continued)			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
Total Engine Airflow Bias Reset Piston Orifice 25.2.20.20	To delay translation of engine total airflow reset piston in direction to remove the reset.	Plugged orifice.	SLTO: Translation of the airflow reset piston in reset direction not affected.	None	Not affected	Not affected	None
			Translation of airflow reset piston in reset removal direction slower than normal, rate dependent upon leakage through reset piston check valve.	Removal of total airflow bias will be slower than normal after large rapid PLA augmentation transients, initiation of augmentation and zone transfer.	Engine not appreciably affected.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected.	None. If maximum F_n desired, same as SLTO.
Total Engine Airflow Bias Reset Piston 25.2.20.21	On receiving appropriate signals, provides bias to the engine total airflow control system to increase airflow in order to provide additional surge margin during large rapid augmented PLA movements, augmentation initiation, and augmented zone transfer.	a. Seizure in non-reset position.	SLTO: During transients of large rapid augmented PLA movements, augmented initiation, and zone transfer, the engine total airflow will not be increased during the transients.	Normal engine total airflow increase during augmentation transient periods will not occur.	Some reduction in surge margin during transients.	CR	If desired, use minimum PLA positions for augmentation initiation and zone transfer and use slow augmented PLA movements.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	None	Not affected. If maximum F_n desired, same as SLTO.	Not affected	None. If maximum F_n desired, same as SLTO.
		b. Seizure in Reset Position	SLTO: Failure can only occur during large rapid augmented PLA movements, initiation of augmentation, or zone transfer. If failure occurs, the engine total airflow bias remains in effect during augmentation.	Engine total airflow increase normally associated during transients only, will now be in effect during augmentation.	F_n = 95% F_{nma}.	AF and CR	None
			Cruise: Same as SLTO	Same as SLTO	F_n = 95% F_{nma}.	Same as SLTO	None
			Landing: Not applicable. If maximum F_n desired and failure occurs, same as SLTO.	None	Not applicable. If maximum F_n desired and failure occurs, same as SLTO.	Not applicable	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Primary Combustor Pressure, P_B, Sense System 25.2.21	Provides a multiplying force proportional to P_B to the duct heater schedule and fuel flow computation system.						
P_B Sense Bellows 25.2.21.1 Or P_B Evacuated Bellows 25.2.21.2	Transmits P_B pressure level as a force to the P_B mulitplying lever. Supplies additive force proportional to ambient pressure so that P_B force transmitted to P_B multiplying lever is based on P_B absolute pressure level.	Sense bellows rupture or Evacuated bellows leak or rupture.	SLTO: Effective P_B is less than normal resulting in duct heater fuel flow approximately 90% of normal.	Duct heater fuel flow less than normal.	F_N = 95% F_{nma}	AF and CR	Remote duct heater fuel flow adjustment will essentially compensate for reduction in effective P_B.
			Cruise: Same as SLTO except duct heater fuel flow is approximately 80% of normal.	Same as SLTO	F_N = 85% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Not affected If maximum F_n desired, same as SLTO.	None	Not affected If maximum F_n desired, same as SLTO.	Not affected	None If maximum Fn desired, same as SLTO.
P_B Multiplying Lever Seal Bellows 25.2.21.3	Seals P_B bellows ambient pressure cavity from control case pressure.	Leak or rupture	SLTO: Fuel leakage overboard through the P_B housing drain. Rate of fuel leakage restricted by an orifice. P_B sense system essentially not affected by fuel pressure in ambient cavity.	Overboard drain leakage from P_B housing drain.	Not affected	CR	None
			Cruise: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Scheduling and Fuel Flow Computation System 25.2.22	A feedback force balance system that computes and controls duct heater fuel flow. Fuel flow ratio, W_f/P_b, is scheduled as a function of PLA and T_{t2}. W_f/P_b is multiplied by the P_b signal from the duct heater P_b sense system to arrive at the desired duct heater fuel flow. The system controls the duct heater throttle valve system by providing a fuel flow demand signal and receiving a fuel flow feedback signal.						

The Failure Mode Index Number for this unitized control system has been reserved in the event of future need. Parts within this system consist of a cam, springs, rollers, and various linkages which are considered to be designed with sufficient margin to preclude their breakage. It was assumed that failure of the parts within this system will not occur. Failures within other unitized control systems will affect this system and the total effect of such failures including the effect on the duct heater scheduling and fuel flow computation system are presented in the analysis of the appropriate system.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Fuel Inlet Filter 25.2.23	Contamination protection. All fuel entering the duct heater system is passed through a 20 mesh strainer. After passing through the strainer, servo fuel is passed through a 40 micronic wash type filter. A relieving bypass valve is provided for the servo filter.	Excessive contamination deposited on servo filter	SLTO: When fuel pressure drop across the servo filter exceeds a preset level, the servo filter bypass valve opens allowing strained inlet fuel to bypass the servo filter. Contaminant may enter the duct heater servo system. Dependent on the size and amount of contaminant, failures may occur in the control servo system.	Excessive contaminant in the filter and corrective action can be controlled in most instances by normal periodic inspection and maintenance.	No immediate effect.	No immediate effect.	None
			Cruise: Same as SLTO	Same as SLTO	No immediate effect.	No immediate effect.	None
			Landing: Same as SLTO	Same as SLTO	No immediate effect.	No immediate effect.	None

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Unitized Control (Con't.)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Throttle Valve System 25.2.24	Duct heater fuel flow metering system. The duct heater schedule and fuel flow computation system controls the positioning of the throttle valve, and the throttle valve pressure regulating system controls the fuel differential pressure across the throttle valve so that throttle valve position is a direct metered fuel flow function.						
Duct Heater Throttle Valve Pilot Valve 25.2.24.1	Positions the throttle valve by modulating throttle valve servo pressure in response to the fuel flow signal from the duct heater schedule and fuel flow computation system.	a) Seizure in decrease metered fuel flow side of null	SLTO: Duct heater throttle valve is scheduled to minimum fuel flow position.	Duct heater blows out if on or can not be initiated if off.	Duct heater fuel flow scheduled at minimum flow resulting in duct heater blow out if on or can not be initiated if off. Fn = 65% Fnma	AF and CR	Reduce to and/or maintain non augmented PLA range. Adjust Fn level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Duct heater fuel flow at minimum flow value.	FN = 25% FNMA	Same as SLTO	Adjust Fn level on unaffected engines to obtain desired aircraft conditions.
			Landing: Not affected if maximum Fn desired, same as SLTO	Duct heater blows out if augmenting during descent None	Duct heater blows out if augmenting during descent Not Affected. If maximum F_n desired, same as SLTO.	Not affected.	If duct heater blows out on descent, same as SLTO. None If maximum Fn desired, same as SLTO

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Unitized Control (Con't.)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Throttle Valve Pilot Valve 25.2.24.1 (continued)		b) Seizure in increase metered fuel flow side of null	SLTO: Duct heater throttle valve is scheduled to maximum fuel flow position. Duct heater fuel flow can not be modulated with PLA or T_{t2} bias.	Duct heater fuel flow scheduled to maximum fuel flow and can not be modulated with PLA. On augmented climb, duct heater will eventually blow out	Fn = 105% Fnma	AF and CR	After SLTO, Retard to and/or maintain non augmented PLA range. Adjust Fn level on unaffected engines to obtain desired aircraft conditions. Use augmentation for emergency use only.
			For duct heater shut off, circulation flow will remain at maximum duct heater fuel flow.	For duct heater shut off, circulation fuel flow will remain at maximum duct heater fuel flow	Not affected, system can handle level of circulation flow	CR	None
			Cruise: Same as SLTO	Same as SLTO, except engine surge and duct heater blows out	Same as SLTO except engine surge and duct heater blow out. Fn = 20% Fnma	Same as SLTO	Retard to and/or maintain non augmented PLA range. Adjust Fn level on unaffected engines to obtain desired aircraft conditions.
			Landing: Not affected. If maximum Fn desired, same as SLTO	Same as SLTO	Not affected. If maximum Fn desired, Same as SLTO	Not affected	None If maximum Fn desired augmentation available for emergency conditions.

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Unitized Control (Con't.)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct heater Throttle valve 25.2.24.2	Duct heater fuel flow metering valve	Seizure	SLTO: Duct heater fuel flow remains at level scheduled at time of failure and can not be modulated with PLA or Tt_2 bias.	No immediate effect Duct heater fuel flow can not be modulated with PLA and will not follow normal Tt_2/ altitude schedule. Will eventually blow out on climb.	No immediate effect Duct heater fuel flow will not follow normal PLA/altitude schedule. As altitude is increased duct heater fuel flow will eventually be excessive for conditions and duct heater will blow out.	No immediate effect CR When duct heater fuel flow becomes excessive for conditions, AF	None When necessary, reduce to and/or maintain non augmented PLA range. Adjust Fn level on unaffected engine to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	No immediate effect. If conditions significantly change from those at time of failure, duct heater fuel flow will be improper and may result in duct heater blow out	No immediate effect	None If duct heater blows out, reduce to and/ or maintain non augmented PLA range. Adjust Fn level on unaffected engines to obtain desired aircraft conditions.
			Landing: Not affected. If maximum Fn desired, same as SLTO	Not affected	Not affected. If maximum Fn desired, duct heater fuel flow will remain at non augmented circulation flow level resulting in essentially minimum augmentation level. Fn = 65% Fnma	Not ffected	None If maximum Fn desired adjust Fn level on unaffected engines to obtain desired aircraft conditions.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Throttle Valve Pressure Regulating System 25.2.25	Regulates throttle valve differential pressure to a constant value so that throttle valve position is proportional to metered fuel flow.						
In Line Pressure Regulating Valve Sensor 25.2.25.1 or In Line Pressure Regulating Valve Integral Piston 25.2.25.2	Modulates pressure regulating valve integral piston pressure in response to sensor throttle valve differential pressure. Provides integral regulation function to pressure regulating valve spring for improved regulation by minimizing spring rate affect on pressure regulating valve position.	a) Sensor seizure in position from null to increase throttle valve differential pressure. or Piston seizure in full authority position for increase in throttle valve differential pressure.	SLTO: Pressure regulating valve integral piston at full authority position for increase in throttle valve differential pressure. Throttle valve differential pressure regulation will be maintained by the proportional pressure regulating valve at a level approximately 17% higher than normal. Approximately 8% increase in duct heater fuel flow.	Approximately 8% increase in duct heater fuel flow.	Duct heater fuel flow higher than normal.	CR	Adjust PLA or remote duct heater fuel adjustment to correct for fuel flow increase.
			Cruise: Same as SLTO except throttle valve differential pressure increased approximately 10% and approximately 5% increase in duct heater flow.	Approximately 5% increase in duct heater fuel flow.	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected.	None. If maximum F_n desired, same as SLTO.
		b) Sensor seizure in position from null to decrease throttle valve differential pressure. or Piston seizure in full authority position for decrease in throttle valve differential pressure.	SLTO: Pressure regulating valve integral piston at full authority position for decrease in throttle valve differential pressure. Regulation will be maintained by the proportional pressure regulating valve at a level approximately 17% lower than normal. Approximately 8% decrease in duct heater fuel flow.	Approximately 8% decrease in duct heater fuel flow.	Duct heater fuel flow lower than normal.	CR	Adjust remote duct heater fuel adjustment to correct for fuel flow decrease.
			Cruise: Same as SLTO except throttle valve differential pressure decreased approximately 10%. Approximately 5% decrease in duct heater fuel flow.	Approximately 5% decrease in duct heater fuel flow.	Same as SLTO except F_n = 95% F_{nma}	AF and CR	Same as SLTO

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
			Landing: Not affected. If maximum F_n desired, same as SLTO.	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected.	None. If maximum F_n desired, same as SLTO.
In-Line Pressure Regulating Valve 25.2.25.3	Regulates throttle valve differential pressure by varying restriction in metered flow path.	Seizure	SLTO: Lose in-line pressure regulator modulation to control throttle valve differential pressure. Pump controller will maintain pressure drop across throttle valve and in-line pressure regulator to normal value. Normal duct heater fuel flow will be maintained for conditions existing at time of failure.	Duct heater fuel flow will deviate from normal scheduling as conditions change from those existing at time of failure.	No immediate effect.	No immediate effect.	None
			As conditions change from those at time of failure, effect will be as follows:				
			Scheduled duct heater throttle valve increase flow positioning will result in duct heater fuel flow being less than normal. Amount of flow deviation from normal dependent on amount of schedule change from that existing at time of failure. Duct heater fuel flow increase limited to a maximum of approximately 60% greater than that at time of failure.	Duct heater fuel flow less than normal.	Duct heater fuel flow less than normal with deviation dependent on amount of schedule change from conditions existing at time of failure.	AF and CR	Adjust F_n level on unaffected engine to obtain desired aircraft conditions.
			Scheduled duct heater throttle valve decrease flow positioning will result in duct heater fuel flow being greater than normal for the new position. Amount of flow deviation from new position normal dependent on amount of schedule change from that existing at time of failure. Level above new position normal will not exceed approximately 60% greater than new position normal.	Duct heater fuel flow greater than normal	Duct heater fuel flow greater than normal with deviation dependent on amount of schedule change from condition existing at time of failure.	CR	Duct heater fuel flow correction can be made with PLA until reaching min augmented PLA position. If minimum augmentation desired, reduce PLA to non-augmented on affected engine and adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected.	None. If maximum F_n desired same as SLTO.
In-Line Pressure Regulating Valve Metered Pressure Signal Damping Orifice 25.2.25.4	Dampens metered pressure signal for duct heater fuel flow stability	Orifice plugs	SLTO: Fuel pressure on metered signal side of pressure regulating valve will tend to follow integral piston modulated pressure. Throttle valve differential pressure will tend to oscillate approximately ± 10% from normal. Duct heater fuel flow will tend to oscillate approximately ± 5% from normal.	Duct heater fuel flow flow will tend to oscillate approximately ± 5% from normal.	Duct heater fuel flow will tend to oscillate approximately ± 5% from normal.	CR	After SLTO if oscillations are objectionable, reduction of PLA will minimize the magnitude of the oscillations.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected. If maximum F_n desired, same as SLTO.	Same as SLTO	Not affected. If maximum F_n desired, same as SLTO.	Not affected.	None. If maximum F_n desired, same as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Secondary Cooling Flow Valve 25.2.26.1	Ensures minimum fuel flow level from duct heater pump to unitized control for proper engine oil cooling.	a. Seizure in non-bypass position.	SLTO: This is normal position for augmentation at this condition. Also this is normal position for all nonaugmented conditions.	None	Not affected	Not affected	None
			During augmented climb when metered duct heater fuel flow is reduced below approximately 3000 pph, the throttle valve servo will drive the secondary cooling valve to the bypass condition. See seizure in bypass position.	See item (b) seizure in bypass position.	See item (b) seizure in bypass position.	See item (b) seizure in bypass position.	See item (b) seizure in bypass position.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Not affected	None	Not affected	Not affected	None
		b. Seizure in bypass position.	SLTO: Not applicable.	Not applicable	Not applicable	Not applicable	Not applicable
			During climb when augmented metered duct fuel flow is below approximately 3000 pph, duct heater throttle valve positioning will drive the cooling valve into the bypass position required to maintain proper duct heater pump delivered fuel flow for adequate oil cooling. On subsequent increase in metered duct heater fuel flow above 3000 pph or duct heater fuel shutoff, the seized cooling flow valve will remain in the bypass position. Amount of bypass fuel flow dependent on lowest level of duct heater metered flow before flow increased or shut off.	After reducing duct heater metered flow below 3000 pph, subsequent increase in this flow or flow shutoff will result in measured duct heater fuel flow being higher than normal.	Not affected	CR	None
			Cruise: Same as SLTO, low duct heater fuel flow.	Same as SLTO, low duct heater fuel flow.	Not affected	Same as SLTO, low duct heater fuel flow.	None
			Landing: Not applicable	Not applicable	Not applicable	Not applicable	Not applicable

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Duct Heater Fuel Turbopump Controller System (Butterfly Valve Remote Mounted) 25.2.27	Controls bleed air to pump turbine to drive the pump at the lowest speed which will provide the requested fuel pressure. A remote mounted actuator is utilized to modulate a butterfly valve in the duct supplying bleed air to the pump turbine						
Pilot Valve - Regulating Valve Downstream Pressure 25.2.27.1	Provides direct input to remote butterfly actuator and is half of split pilot valve system controlling duct heater control inlet to regulating valve downstream differential pressure.	Seizure (Low differential pressure position.)	SLTO: Butterfly valve positioned to maximum position. Pump speed is increased and duct heater fuel system pressure level is increased.	Ground check butterfly valve position indicator will show butterfly valve open at engine shutdown and all nonaugmented engine operating conditions.	Not affected. Duct heater control will maintain proper fuel scheduling.	CR	None
or			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
Pilot Valve - Control Inlet Pressure 25.2.27.2	Other half of split pilot valve system (see above). Provides input to integrating piston and pilot valve.	Seizure (Low differential pressure position.)	Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
Pilot Valve - Regulating Valve Downstream Pressure 25.2.27.1 or	See previous functional description.	Seizure (High differential pressure position.)	SLTO: Butterfly valve positioned to minimum position. Pump speed reduced to low level. Duct heater fuel flow reduced to essentially zero.	Duct heater fuel flow essentially zero. Duct heater shuts off if on or cannot be initiated if off.	F_n = 65% $F_{n\ ma}$.	AF and CR	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
Pilot Valve - Control Inlet Pressure 25.2.27.2	See previous functional description.	Seizure (High differential pressure position.)	Cruise: Same as SLTO	Same as SLTO	F_n = 20% $F_{n\ ma}$. In addition, oil temperature will increase and may eventually exceed limits due to loss of duct heater oil cooler fuel flow.	Same as SLTO. Also, may have IFS.	Same as SLTO. In addition, monitor engine oil temperature. May be necessary for IFS, and if necessary to maintain oil temperature limit, reduce aircraft speed to subsonic conditions.
			Landing: Same as SLTO. Duct heater fuel flow not available.	Same as SLTO	Not affected. Maximum F_n limited to SLTO conditions.	Same as SLTO	None. Same as SLTO if maximum F_n desired.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Integrating Piston and Pilot Valve 25.2.27.3	Provides integrating function for positioning of pilot valve.	Seizure (Butterfly valve open position.)	SLTO: Dependent on seizure position.				
			For seizure close to null where the split pilot valve can handle the increased servo flow, the split pilot valve will still control the pump butterfly valve although control will be somewhat slower than normal. Duct heater fuel system fuel pressure will tend to be increased and will fluctuate. Duct heater fuel flow will tend to fluctuate.	Duct heater fuel flow will tend to fluctuate.	Essentially not affected.	CR	None
			For seizure positions of larger excursion from null, the butterfly valve positioned to maximum position. Pump speed is increased and duct heater fuel system pressure level is increased.	Ground check butterfly valve position indicator will show butterfly valve open at engine shutdown and all nonaugmented engine operating conditions.	Not affected. Duct heater control will maintain proper fuel scheduling.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
		Seizure (Butterfly valve closed position.)	SLTO: Dependent on seizure position.				
			For seizure close to null where the split pilot valve can handle the increased servo flow, the split pilot valve will still control the pump butterfly valve although control will be somewhat slower than normal. Duct heater fuel flow will tend to fluctuate.	Duct heater fuel flow will tend to fluctuate.	Essentially not affected.	CR	None
			For seizure positions of larger excursions from null, the butterfly valve positioned to minimum position. Pump speed reduced to low level. Duct heater fuel flow reduced to essentially zero.	Duct heater fuel flow essentially zero. Duct heater shuts off if on or cannot be reinitiated if off.	F_n = 65% F_n ma.	AF and CR. Also, may have IFS.	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
			Cruise: Same as SLTO	Same as SLTO	F_n = 20% $F_{n\ ma}$. In addition, oil temperature will increase and may eventually exceed limits due to loss of duct heater oil cooler fuel flow.	Same as SLTO. Also, may have IFS.	Same as SLTO. In addition, monitor engine oil temperature. May be necessary for IFS and if necessary to maintain oil temperature limit, reduce aircraft speed to subsonic conditions.
			Landing: Same as SLTO. Duct heater flow may not be available. See SLTO.	Same as SLTO	Not affected. Maximum F_n may not be available. See SLTO.	Not affected	None. Same as SLTO if maximum F_n desired.
Remote Butterfly Valve Actuator Piston 25.2.27.4	Modulated by pump controller to position the pump butterfly valve.	Seizure (Duct heater on position.)	SLTO: For duct heater fuel flow demand near or less than that at time of failure, pump speed and duct heater fuel system pressure level will be higher than normal as fuel flow demand is decreased from that at time of failure.	Ground check butterfly valve position indicator will show butterfly valve in augmented position at engine shutdown and all nonaugmented engine operating conditions.	Not affected. Duct heater control will maintain proper fuel scheduling.	CR	None
			For duct heater fuel flow demand considerably higher than that at time of failure, energy to pump will not be sufficient to meet demand. The duct heater system in-line pressure regulating valve will attempt to maintain throttle valve differential pressure and may impose too high a pressure level for the fuel pump to handle. Duct heater fuel flow may decrease to essentially zero.	Duct heater may flame out.	If duct heater flames out, F_n = 65% F_n.	If duct heater flames out, AF and CR.	If duct heater flames out, reinitiate if desired. Limit PLA range to slightly less than flame out position and lower.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except F_n = 20% $F_{n\ ma}$.	Same as SLTO	Same as SLTO
			Landing: Not applicable. If seizure occurs in duct heater off position, duct heater fuel flow not available.	Not applicable	Not applicable. If maximum F_n desired, F_n = 65% $F_{n\ ma}$.	Not applicable	Not applicable. If maximum F_n desired, maintain PLA in nonaugmented range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Remote Butterfly Valve Actuator Piston 25.2.27.4 (continued)		Seizure (Duct heater off position.)	SLTO: Not applicable for duct heater on conditions.	Not applicable	Not applicable	Not applicable	None
			For duct heater off conditions, cannot initiate duct heater fuel flow.	Duct heating cannot be initiated.	F_n = 65% $F_{n\ max}$.	AF and CR	Maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except for condition where duct heating cannot be initiated. F_n = 20% $F_{n\ max}$.	Same as SLTO	Same as SLTO
			Landing: Not affected. Duct heating fuel flow not available.	Not affected.	Not affected. Maximum F_n limited to SLTO non-augmented conditions.	Same as SLTO	None. Same as SLTO non-augmented conditions if maximum F_n desired.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Compressor Inlet Guide Vane Control System 25.2.28	Provides high pressure fuel signals to the compressor inlet guide vane actuators for positioning in either the start-cruise or SLTO positions. Positioning is controlled as a function of N_2 and T_{t2}.						
Compressor Inlet Guide Vane Pilot Valve 25.2.28.1 or Compressor Inlet Guide Vane Control Valve 25.2.28.2	Controls positioning of the compressor inlet guide vane control valve as a function of N_2 and T_{t2}. / Controls positioning of the compressor inlet guide vane actuators as signaled by the compressor inlet guide vane pilot valve.	Seizure in SLTO position / Seizure in SLTO position	SLTO: No immediate effect. On climb the compressor inlet guide vanes will not be positioned to the start-cruise position.	None. Some increase in engine total airflow in range where compressor inlet guide vanes normally in start-cruise position.	No immediate effect. In range where compressor inlet guide vanes normally at start-cruise position there will be an increase in engine total airflow with increase reaching approximately 5% above normal at cruise.	No immediate effect. CR	None
			Cruise: Normally not applicable	Not applicable	Not applicable	Not applicable	None
			If N_2 reduced below actuation level and seizure occurs, compressor inlet guide vanes remain in SLTO position after seizure.	Approximately 5% increase in engine total airflow.	$F_n = 95\% \ F_{nma}$	AF and CR	If desired, use remote engine total airflow adjustment.
			Landing: For this failure to occur, landing N_2 must be above actuation level to be in SLTO position. If failure occurs, the compressor inlet guide vanes will remain at the SLTO position when N_2 reduced below actuation level.	None	Not appreciably affected	CR	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Compressor Inlet Guide Vane Pilot Valve 25.2.28.1	See previous description	Seizure in start-cruise position	If pilot valve seizes in this position during start or cruise conditions, it will be driven to the SLTO position the first time SLTO positioning is scheduled. See previous analysis for seizure in SLTO position.				
Compressor Inlet Guide Vane Control Valve 25.2.28.2	See previous description	Seizure in start-cruise position	SLTO: Not applicable	Not applicable	Not applicable	Not applicable	None
			Cruise: No immediate effect. On descent, the compressor inlet guide vanes will remain in the start-cruise position	None During descent at normal SLTO position of compressor, inlet guide vanes:	No immediate effect	No immediate effect	None
				Minor increase in N_2 and decrease in duct nozzle area at lower three-fourths of non-augmented PLA range.	At lower three-fourths non-augmented PLA range, engine not appreciably affected.	Not appreciably affected	None
				At upper quarter of nonaugmented PLA range, N_2 increase and duct nozzle area decrease as altitude and T_{t2} decrease.	Some reduction in F_n with reduction becoming larger as altitude and T_{t2} decrease.	AF and CR	Use PLA or remote EPR adjustment to adjust F_n level on affected engine.
				At augmented PLA range, N_2 increase and duct nozzle decrease with eventual engine surge as altitude and T_{t2} decrease.	Some reduction in F_n with reduction becoming larger as altitude and T_{t2} decrease. Eventual engine surge limiting F_n to less than normal maximum nonaugmented.	Same as above	[illegible] EPR [illegible] F_n level [illegible] engine. Adjust F_n level on unaffected engines to obtain desired aircraft conditions. Affected engine eventually limited to non-augmented PLA range.
			Landing: For this failure to occur, N_2 must be reduced below actuation level. If failure then occurs, no immediate effect.	None	No immediate effect	No immediate effect	None
			If maximum F_n desired, compressor inlet guide vanes will remain in start-cruise position.	If maximum F_n desired, N_2 higher than normal, duct nozzle area less than normal. Engine surge if augmentation attempted.	If maximum F_n desired, engine surge if augmentation attempted. F_n = 40% Fnma. Reverse F_n lower than normal.	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

No.___ of___

Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Reverser-Suppressor Control System 25.2.29	Provides fuel pressure to the reverser-suppressor actuator for positioning the clamshells. Positioning is controlled by PLA when authorized by N_2 level. The PLA failure effects are analyzed in the power lever boost and sequencing system section 25.2.2 The failure effects of the speed authority are analyzed in the low speed protection valve section 25.2.15.						
Reverser-Suppressor Control Valve 25.2.29.1	Control positioning of the reverser-suppressor actuators as signaled by PLA when authorized by N_2.	a) Seizure of control valve or piston in takeoff position.	SLTO: Not affected Cruise: Not affected Landing: Reverser-suppressor actuation to reverse position not available.	None None Cannot retard PLA below reverse idle.	Not affected Not affected Reverse thrust not available.	Not affected Not affected CR	None None When reverse desired, maintain engine at idle. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
or							
Reverser-Suppressor Control Valve Piston 25.2.29.2	Provides force to move control valve to takeoff position.	b) Seizure of control valve or piston in reverse position.	SLTO: Not applicable Cruise: Not applicable Landing: Reverser must be actuated for this failure to occur. If reverse is selected and failure occurs, reverser-suppressor stays in the reverse position.	Not applicable Not applicable Reverser-suppressor remain in reverser position.	Not applicable Not applicable Only reverse F_n available.	Not applicable Not applicable AF and CR	None None Maintain engine at idle or shut off. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Compressor Bleed Control System 25.2.30	Provides high pressure air signal to the compressor bleed actuators for positioning the bleeds.						
Compressor Bleed Pilot Valve 25.2.30.1	Controls positioning of the compressor bleed control piston as a function of N_2 and T_{t2}	Seizure in bleeds closed position	SLTO: Compressor bleeds remain in closed position	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
or			Landing: Same as SLTO	Compressor bleeds remain closed when N_2 reduced to idle.	No immediate effect Engine may surge during acceleration while in reverse or if maximum F_n desired.	No immediate effect OR If engine surge, AF	None If engine surges, retard PLA to idle or shutoff engine. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
Compressor Bleed Remote Control Piston 25.2.30.2	Controls positioning of the bleed control poppet valves as signaled by the bleed pilot valve.	Seizure in bleeds closed position					
or							
Compressor Bleed Remote Control Poppet Valve 25.2.30.3	Positioned by control piston to supply compressor discharge air pressure to bleed actuators to close the bleeds.	Seizure in bleeds closed position					

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Compressor Bleed Pilot Valve 25.2.30.1	See previous description	Seizure in bleeds open position	If pilot valve seizes in this position during start, it will be driven to the bleeds closed position the first time bleeds closed is scheduled. The previous analysis for seizure in bleeds closed position is then applicable. If seizure in bleeds open position during landing, there is no effect until reverse F_n application of which t' . the pilot valve is driven to the bleeds close position and subsequent engine power reductions to idle followed by accelerations .ay result in engine surge.				
Compressor Bleed Remote Control Piston 25.2.30.2	See previous description	Seizure in bleeds open position	SLTO: Not applicable	None	Not applicable	Not applicable	None
			Cruise: Not applicable	None	Not applicable	Not applicable	None
			Landing: Speed must be reduced to near idle for this failure to occur. If failure occurs, subsequent accelerations will result in bleeds remaining open.	Bleeds stay in open position	Reduction in reverse F_n. If maximum F_n desired, F_n = 70% F_{max}.	OK If maximum F_n desired AF	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
or							
Compressor Bleed Remote Control Poppet Valves 25.2.30.3	See previous description	Seizure in bleeds open position					
Compressor Bleed Remote Control Bellows Seal 25.2.30.4	Seals low pressure fuel section from ambient pressure cavity	a) Rupture in fuel side	SLTO: Fuel leakage into drain cavity and out overboard drain.	Fuel leakage from compressor bleed remote control overboard drain.	Not affected	OK	None
			Cruise: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Not affected	Same as SLTO	None
		b) Rupture in ambient side	SLTO: Lose seal between overboard drain cavity and ambient cavity. If fuel side of bellows then ruptures (double failure), the overboard drain should prevent fuel entering the ambient cavit	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Servo Pressure Regulating System 25.2.31	Regulates servo pressure to a constant level above drain pressure for improved control scheduling accuracy.						
Proportional Valve 25.2.31.1	Provides direct proportional regulation of a portion of the servo flow plus provides a modulated pressure signal to the integral valve.	Seizure	SLTO: Lose proportional regulation and signal modulation to integral valve. Dependent on flow force on integral valve and pressure forces on both ends of the integral valve, the integral valve will saturate closed or open.				
			If integral valve opens, servo pressure will be increased to control inlet pressure. Control schedule accuracy will be moderately impaired.	Control functions may not follow normal scheduling.	Moderate effect on control scheduling.	CR	PLA, remote EPR, and remote duct heater fuelflow adjustments may be used as necessary to correct scheduling.
			If integral valve closes, servo pressure will be reduced substantially resulting in loss of control scheduling authority.	Control functions will depart significantly from normal scheduling.	Power reduction.	Possible IFS and CR.	Retard SOL to off position. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO. May also use remote airflow adjustment.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
Integral Valve 25.2.31.2	Provides integral regulation of the majority of the servo flow as a function of drain pressure level and a modulated pressure signal from the proportional valve.	Seizure	SLTO: Dependent upon seizure position and servo flow demands, servo pressure will be regulated over a wider pressure range than normal. Control schedule accuracy will be somewhat impaired.	Control functions may not follow normal scheduling or may drift slightly.	Minor or moderate effect on control scheduling.	CR	PLA, remote EPR, and remote duct heater fuel flow adjustments may be used as necessary to correct scheduling.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO. May also use remote airflow adjustment.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Integral Valve Inlet Pressure Supply Orifice 25.2.31.3	The integral valve inlet pressure supply orifice is in series with the drain orifice. The pressure between the two orifices is directed to one end of the integral valve and varies as a function of inlet pressure level. The other end of the integral valve receives the modulated pressure signal from the proportional valve. This system ensures adequate force margin and constant response rate for controlling the integral valve.	Plugged	SLTO: Drain pressure is supplied to one end of the integral valve and valve closes. Servo pressure will be reduced substantially resulting in loss of control scheduling authority.	Control functions will depart from normal scheduling.	Power reduction	IFS and CR	Retard SOL to off position. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
Integral Valve Drain Orifice 25.2.31.4	See previous functional description for integral valve inlet pressure supply orifice.	Plugged	SLTO: Control inlet pressure is supplied to one end of the integral valve and valve opens. Servo pressure will be increased to control inlet pressure. Control schedule accuracy will be moderately impaired.	Control functions may not follow normal scheduling.	Moderate effect on control scheduling.	CR	
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO. May also use remote airflow adjustment.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Drain Pressure Regulating System 25.2.32	Regulates drain pressure (servo sink) to a constant level for improved control scheduling accuracy.						
Proportional Valve 25.2.32.1	Provides direct proportional regulation of a portion of the drain flow plus provides a modulated pressure signal to the integral valve.	Seizure	SLTO: Lose proportional regulation and signal modulation to integral valve. Dependent on flow force on integral valve and pressure forces on both ends of the integral valve, the integral valve will saturate closed or open.				
			If integral valve closes, drain pressure will be regulated by the relief valve at a slightly higher level than normal. Control scheduling accuracy will be somewhat impaired.	None	Negligible effect	Negligible effect	None
			If integral valve opens, drain pressure will be lowered to gas generator pump inlet pressure. Control scheduling accuracy will be impaired to a minor degree.	None	Minor effect	Minor effect	None
			Cruise: Same as SLTO	None	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	None	Same as SLTO	Same as SLTO	None
Integral Valve 25.2.32.2	Provides integral regulation of the majority of the drain flow as a function of drain pressure level and a modulated pressure signal from the proportional valve.	Seizure	SLTO: Dependent upon seizure position and drain flow, drain pressure will be regulated over a wider than normal pressure range. Control schedule accuracy will be impaired to a minor degree.	None	Minor effect	Minor effect	None
			Cruise: Same as SLTO	None	Minor effect	Minor effect	None
			Landing: Same as SLTO	None	Minor effect	Minor effect	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Integral Valve Drain Pressure Orifice 25.2.32.3	The integral valve drain pressure orifice is in series with the servo regulated pressure supply orifice. The pressure between the two orifices is directed to one end of the integral valve and varies as a function of drain pressure level. The other end of the integral valve receives the modulated pressure signal from the proportional valve. This system ensures adequate force margin and constant response rate for controlling the integral valve.	Plugged	SLTO: Servo pressure supply pressure is supplied to one end of the integral valve and valve opens. Drain pressure is lowered to gas generator pump inlet pressure. Control scheduling accuracy will be impaired to a minor degree.	None	Minor effect	Minor effect	None
			Cruise: Same as SLTO	None	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	None	Same as SLTO	Same as SLTO	None
Servo Regulated Pressure Supply Orifice 25.2.32.4	See previous functional description for integral valve drain pressure orifice.	Plugged	SLTO: Drain pressure is supplied to one end of the integral valve and valve closes. Drain pressure will be regulated by the relief valve at a slightly higher level than normal. Control scheduling accuracy will be somewhat impaired.	None	Negligible effect	Negligible effect	None
			Cruise: Same as SLTO	None	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	None	Same as SLTO	Same as SLTO	None
Proportional Valve Evacuated Bellows 25.2.32.5	Provides an absolute pressure reference for the proportional valve so that drain pressure is regulated to a fixed level.	Rupture	SLTO: Drain pressure regulated by The relief valve at a slightly higher level than normal. Control scheduling accuracy will be somewhat impaired.	None	Negligible effect	Negligible effect	None
			Cruise: Same as SLTO	None	Negligible effect	Negligible effect	None
			Landing: Same as SLTO	None	Negligible effect	Negligible effect	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Relief Bellows 25.2.32.6	Provide secondary regulation capability at a level slightly above normal regulation in the event of primary regulation failure.	Rupture	SLTO: Not affected. Secondary regulation if needed would regulate drain pressure at a level higher than original setting. A failure in the primary system (double failure) must also be present for this condition to exist.	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Thermal Bypass System 25.2.33	Bypasses a portion of the gas generator control pump interstage return fuel to the aircraft fuel tanks when control inlet fuel temperature reaches a preset level to prevent fuel temperature from becoming excessive. A gas generator fuel level bias varies the initiation of bypass to tank so that the bypass occurs at a lower fuel temperature at low levels of gas generator metered fuel flow.						
Thermal Bypass Valve Pilot Valve 25.2.33.1	Provides signal to position the thermal bypass valve as signaled by the fuel temperature sensor valve.	Seizure in bypass to tank position	SLTO: Not applicable	Not applicable	Not applicable	Not applicable	None
			Cruise: Not applicable During descent the thermal bypass valve will be scheduled to the bypass position. If seizure occurs, the valve will remain in this position after seizure.	Not applicable None	Not applicable Not affected	Not applicable Not affected	None None
or							
Thermal Bypass Valve 25.2.33.2	Positioned by the pilot valve to port all bypass fuel to pump interstage or port part of this fuel to tank.	Seizure in bypass to tank position.	Landing: Not applicable	Not applicable	Not applicable	Not applicable	None
or							
Thermal Bypass Valve Piston 25.2.33.3	Provides positive force to load the valve in the non-bypass direction.	Seizure in bypass to tank position.					
or							
Fuel Temperature Sensor Valve 25.2.33.4	Senses control inlet fuel temperature and provides a signal to the pilot valve proportional to fuel temperature.	Seizure in bypass to tank position.					
or							
Pilot Valve Supply Fixed Orifice 25.2.33.6	Permits modulation of pressure signal to the pilot valve by the fuel temperature sensor.	Plugged					

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JTF17 FAILURE MODE & EFFECT ANALYSIS

No.____ of____

Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Thermal Bypass Pilot Valve 25.2.33.1 or Thermal Bypass Valve 25.2.33.2 or	See previous description / See previous description	Seizure in non-bypass position / Seizure in non-bypass position	SLTO: Thermal bypass valve remains in non-bypass position.	None	Not affected	Not affected	None
			Cruise: Same as SLTO During descent where thermal bypass valve normally scheduled to by-pass position, fuel temperature will increase higher than normal.	None Engine oil temperature higher than normal during descent.	Not affected During descent engine oil temperature will be higher than normal	Not affected CR	None An increase in N_2 during decent will be beneficial in reducing engine oil temperature. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Landing: Not affected	None	Not affected	Not affected	None
Thermal Bypass Valve Piston 25.2.33.3 or Fuel Temperature Sensor Valve 25.2.33.4	See previous description / See previous description	Seizure in non-bypass position / Seizure in non-bypass position					
Fuel Level Bias Orifice 25.2.33.5	Permits variation in fuel temperature signal to the thermal bypass valve pilot valve as a function of gas generator metered fuel flow level.	Plugged	SLTO: Fuel bypass to tank will be initiated at lower fuel temperature than normal	None	Not affected	Not affected	None
			Cruise: Same as SLTO	None	Not affected	Not affected	None
			Landing: Same as SLTO	None	Not affected	Not affected	None

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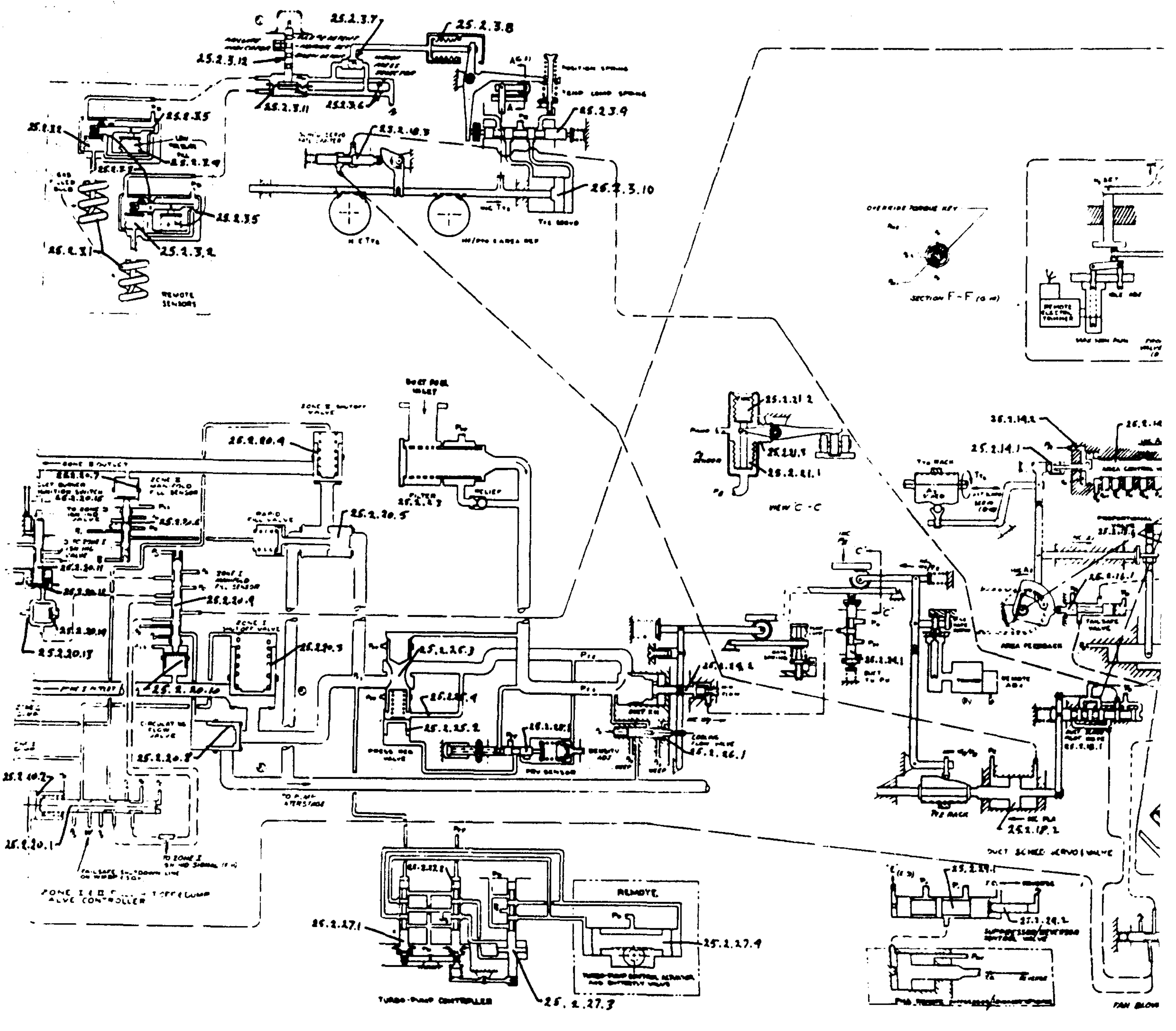

25.2.3.7
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25.2.3.12
25.2.3.11
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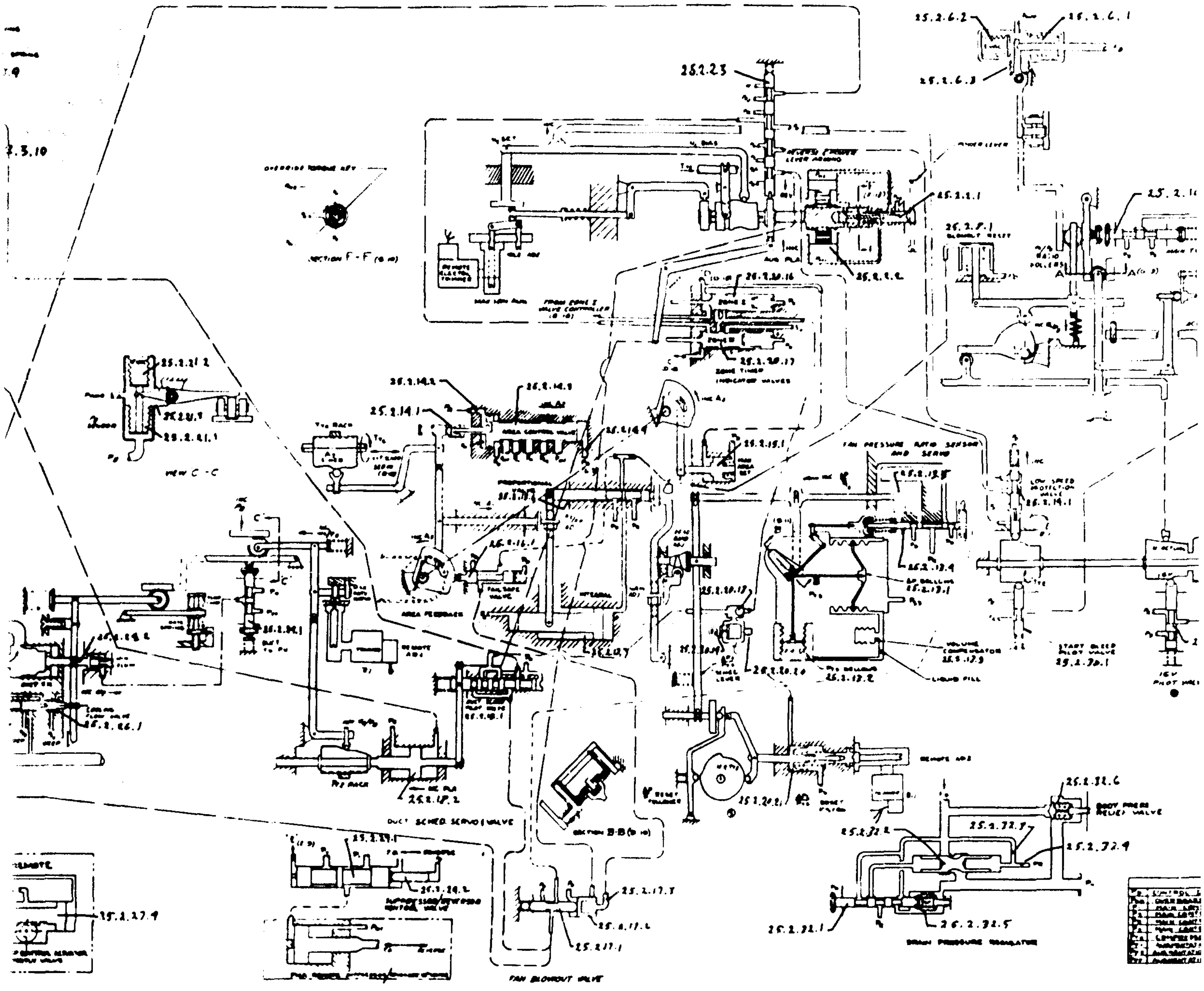
25.2.3.9
25.2.3.5
25.2.3.4
25.2.3.10
25.2.3.1
25.2.3.2
REMOTE SENSORS
SECTION F-F
VIEW C-C
DUCT FUEL INLET
ZONE II SHUTOFF VALVE
25.2.20.4
25.2.20.5
25.2.20.9
25.2.20.3
25.2.20.10
25.2.20.8
25.2.20.17
25.2.20.2
25.2.20.1
25.2.25.3
25.2.25.4
25.2.25.2
25.2.26.1
PRESS REG VALVE
25.2.14.2
25.2.14.1
AREA FEEDBACK
25.2.18.1
25.2.18.2
DUCT SCHED. SERVO VALVE
25.2.29.1
REMOTE
25.2.27.1
25.2.27.4
25.2.27.3
TURBO-PUMP CONTROLLER

A

JTF17 UNITIZED CONTROL SCHEMATIC



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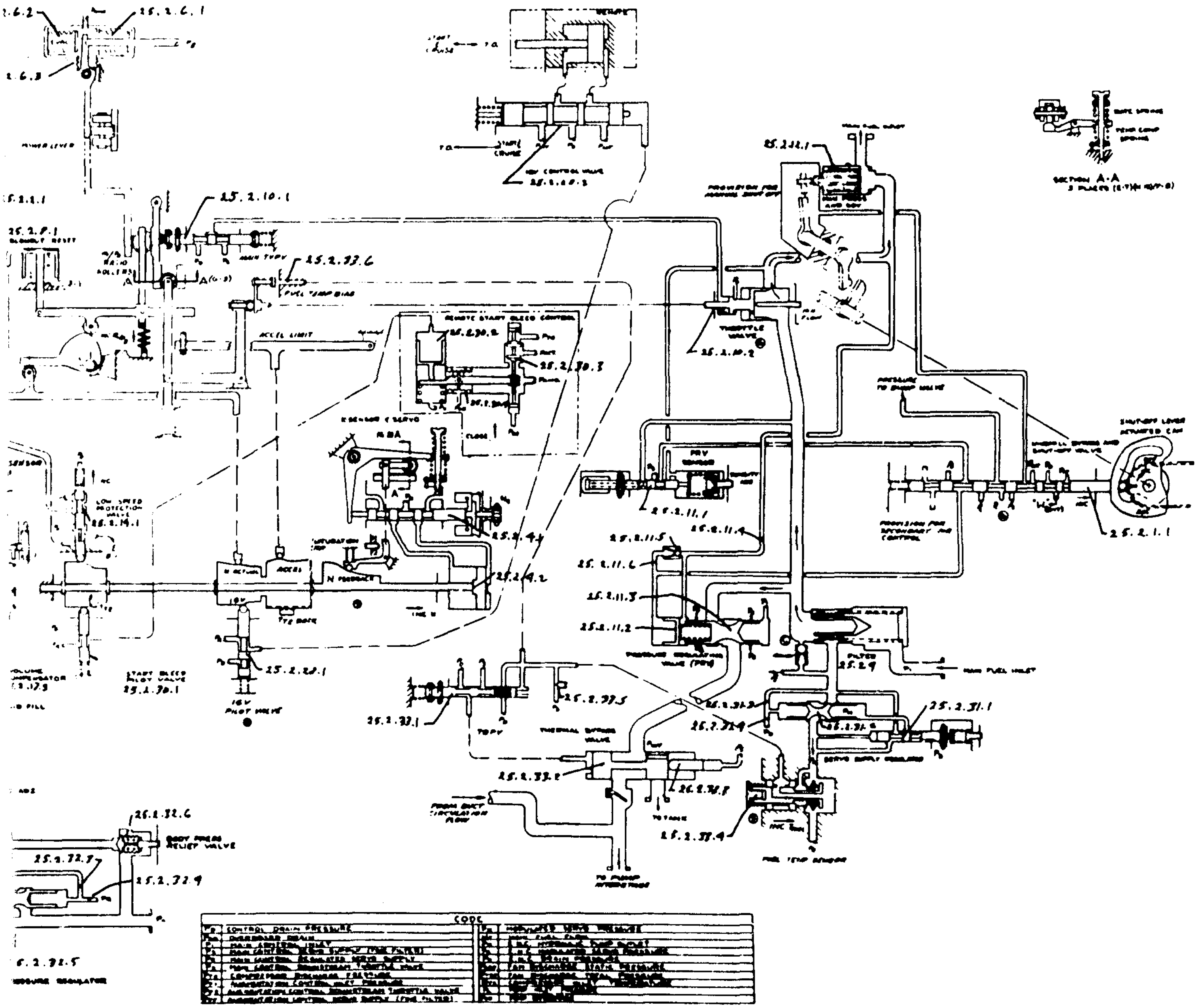
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25.2.33.6
FUEL TEMP BIAS
ACCEL LIMIT
REMOTE START BLEED CONTROL
THROTTLE VALVE
25.2.10.2
25.2.11.1
PRV SENSOR
N FEEDBACK
ACCEL
25.2.11.5
25.2.11.6
25.2.11.3
25.2.11.2
25.2.9
MAIN FUEL INLET
25.2.31.1
25.2.33.5
25.2.33.1
25.2.33.2
25.2.33.4
25.2.1.1
SECTION A-A
25.2.32.6
25.2.32.7
25.2.32.9
BODY PRESS RELIEF VALVE
CODE

25.3, 25.4, and 25.5 FUEL MANIFOLD DRAIN VALVES

A. Description

Fuel manifold overboard drain valves are installed in the gas generator fuel manifold and in each of the duct heater fuel manifolds of the JTF17 engine. These valves open after fuel shut-off to drain residual fuel from the manifolds and nozzles and thereby prevent internal coking and gas generator shutdown fires. The three valves, which are all of common P&WA design, are automatically actuated by individual hydraulic signals from the unitized fuel control. The valve assembly consists of a sliding gate valve actuated by a hydraulic piston.

A cross-section view of the manifold drain valves is presented following the analysis of the valves.

B. ANALYSIS
Sheet 1
25.3, 25.4 and
25.5 Fuel Manifold Drain Valves

JTF17 FAILURE MODE & EFFECT ANALYSIS

No.____ of____

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Gas Generator Manifold Drain Valve 25.3							
Gate Valve 25.3.1	Sequenced to open manifold overboard drain path to drain residual fuel in manifold when gas generator shut down.	a) Seizure in over-board drain closed position.	SLTO: Not Affected. This is normal gas generator operation position.	None	Not Affected.	Not Affected.	None
			Cruise: Same as SLTO	None	Not Affected.	Not Affected.	None
or Valve Piston 25.3.2	Actuates gate valve in response to sequenced signal pressure.		Landing: Same as SLTO On engine shut down residual fuel will not be drained from the gas generator manifold.	None On engine shut down, no fuel dump from gas generator overboard drain.	None May have shut down fire in gas generator combustion section.	Not Affected. CR	None If have shut down fire, motor engine on starter with SOL in Off position.
or Shaft Seal 25.3.3	Seals interstage cavity from manifold connection cavity.	b) Seizure in overboard drain open position.	SLTO: Not Applicable. Overboard drain must be closed for this condition.	Not Applicable.	Not Applicable.	Not Applicable.	Not Applicable.
			Cruise: Same as SLTO If this seizure occurs after an engine shut down, attempted restart will result in most gas generator metered fuel flow being dumped through overboard drain.	Same as SLTO If seizure occurs after an engine shut down, gas generator cannot be started due to loss of fuel overboard.	Same as SLTO If seizure occurs after an engine shut down, gas generator cannot be started.	Same as SLTO If seizure occurs after an engine shut down: CR.	Same as SLTO If seizure occurs after an engine shut down, reduce and maintain SOL in Off position. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
Duct Heater Zone I Manifold Drain Valve 25.4							
Gate Valve 25.4.1	Sequenced to open manifold overboard drain path to drain residual fuel in manifold when Zone I duct heater shut off.	a) Seizure in overboard drain closed position.	SLTO: Not affected during duct heater operation. On duct heater shut down, residual fuel will not be drained from the Zone I manifold.	None On duct heater shut down, no fuel dump from Zone I overboard drain.	Not Affected. Eventual coking of Zone I fuel nozzles.	Not Affected. CR	None None
or Valve Piston 25.4.2	Actuates gate valve in response to sequenced signal pressure.		Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
			Landing: Not Affected. Maximum duct heater fuel flow is available.	Same as SLTO	Not Affected. Maximum F_n is available if desired.	Same as SLTO	None
or Shaft Seal 25.4.3	Seals interstage cavity from manifold connection cavity.						

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JTF17 FAILURE MODE & EFFECT ANALYSIS

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Fuel Manifold Drain Valves (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
		b) Seizure in overboard drain open position.	SLTO: Not applicable during first portion of SLTO where duct heater is in operation.	Not Applicable.	Not Applicable.	Not Applicable.	Not Applicable.
			For seizure occurring after duct heater shut down, subsequent duct heater operation will result in erratic fuel flow to Zone I manifold due to fuel flow in system comprised of intermittent gas generator pump interstage fuel plus duct heater metered fuel flow with a large portion of the total fuel flow being dumped through the overboard drain. Duct heater metered fuel flow intermittently reduced to minimum value. Total airflow bias reset intermittently activated.	Intermittent reduction in duct heater fuel flow and duct nozzle excursions. Excessive overboard drain leakage from Zone I manifold drain valve.	Erratic duct burner operation. At nonaugmented PLA: F_n = 65% F_{nma}.	AP and CR	Reduce to and/or maintain nonaugmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO, except F_n = 20% F_{nma}.	Same as SLTO	Same as SLTO
			Landing: Not Affected. If maximum F_n desired, same as SLTO.	None	Not Affected. Maximum available F_n limited. F_n = 65% F_{nma}.	Same as SLTO	None Same as SLTO if maximum F_n desired.
Duct Heater Zone II Manifold Drain Valve 25.5							
Gate Valve 25.5.1	Sequenced to open manifold overboard drain path to drain residual fuel in manifold when Zone II duct heater shut off.	a) Seizure in overboard drain closed position.	SLTO: Not affected during duct heater operation.	None	Not Affected.	Not Affe[illegible]d.	None
			On duct heater reduction to Zone II shut off, residual fuel will not be drained from Zone II manifold.	On Zone II shut off, no fuel dump from Zone II overboard drain.	Eventual coking of Zone II spraybars.	CR	None
or Valve Piston 25.5.2	Actuates gate valve in response to sequenced signal pressure.		Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
or Shaft Seal 25.5.3	Seals interstage cavity from manifold connection cavity		Landing: Not Affected. Maximum duct heater fuel flow is available.	Same as SLTO	Not Affected. Maximum F_n is available if desired.	Same as SLTO	None

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Sheet I

JTF17 FAILURE MODE & EFFECT ANALYSIS

No.____of____

Fuel Manifold Drain Valves (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
		b) Seizure in overboard drain open position.	SLTO: Not applicable during first portion of SLTO where duct heater Zone II is in operation.	Not Applicable.	Not Applicable.	Not Applicable.	Not Applicable.
			For seizure occurring after duct heater Zone II shut off, subsequent duct heater operation above zone transfer results in erratic fuel flow to Zone II manifold due to fuel flow in system comprised of intermittent gas generator pump interstage fuel plus duct heater metered fuel flow with a large portion of the total fuel flow being dumped through the overboard drain. Zone I metered fuel flow intermittently varied. Duct heater fuel flow intermittently reduced. Total airflow bias reset intermittently activated.	At augmented PLA range above zone transfer, intermittent reduction in duct heater fuel flow and duct nozzle excursions. Excessive overboard drain leakage from Zone II manifold drain port.	Erratic duct burner operation at zone transfer and above. At zone transfer: $F_n = 90\% F_{nma}$.	AF and CR	Reduce to and/or maintain Zone I augmented PLA range or lower. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except for cruise: $F_n = 80\% F_{nma}$.	Same as SLTO	Same as SLTO
			Landing: Not Affected. Maximum duct heater fuel flow not available.	Same as SLTO	Not Affected. Maximum available F_n limited. $F_n = 90\% F_{nma}$.	Same as SLTO	None. Same as SLTO if maximum F_n desired.
FAILURES WITH COMMON EFFECTS FOR GAS GENERATOR AND DUCT HEATER ZONE I AND ZONE II MANIFOLD DRAIN VALVES							
Gate Valve 25.3.1 25.4.1 25.5.1	Sequenced to open manifold overboard drain path to drain residual fuel in manifold when the applicable system shut off.	Valve Leakage (overboard drain closed position).	SLTO: Manifold fuel leakage overboard. Loss of fuel dependent on leakage rate.	Excessive overboard drain leakage from drain valve when the applicable system is in operation.	Dependent on leakage rate. Experience with this type of valve has shown performance not affected.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
Shaft Seal 25.3.3 25.4.3 25.5.3	Seals interstage cavity from manifold connection cavity.	Excessive leakage.	SLTO: When applicable system operating, loss of manifold fuel into interstage cavity. Loss of fuel dependent on leakage rate.	Excessive overboard drain leakage from drain valve when the applicable system is not in operation.	Dependent on leakage rate. Experience with this type of seal has shown performance not affected.	CR	None
			When applicable system not operating and gas generator pump interstage pressure available (including aircraft boost pumps or with engine shut down), loss of interstage fuel into manifold cavity and then out overboard drain. Loss of fuel dependent on leakage rate.				

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JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet 1

No.____ of____

Fuel Manifold Drain Valves

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
Valve Piston Cooling Flow Orifice 25.3.2. 25.4.2 25.5.2	Maintain cooling fuel flow within the signal cavity and interstage cavity.	Contamination	SLTO: If contamination plugs orifice, loss of cooling flow.	None	No immediate effect. May eventually coke within chamber cavities.	No immediate effect.	None
			Cruise: Same as SLTO	None	Same as SLTO	No immediate effect.	None
			Landing: Same as SLTO	None	Same as SLTO	No immediate effect.	None

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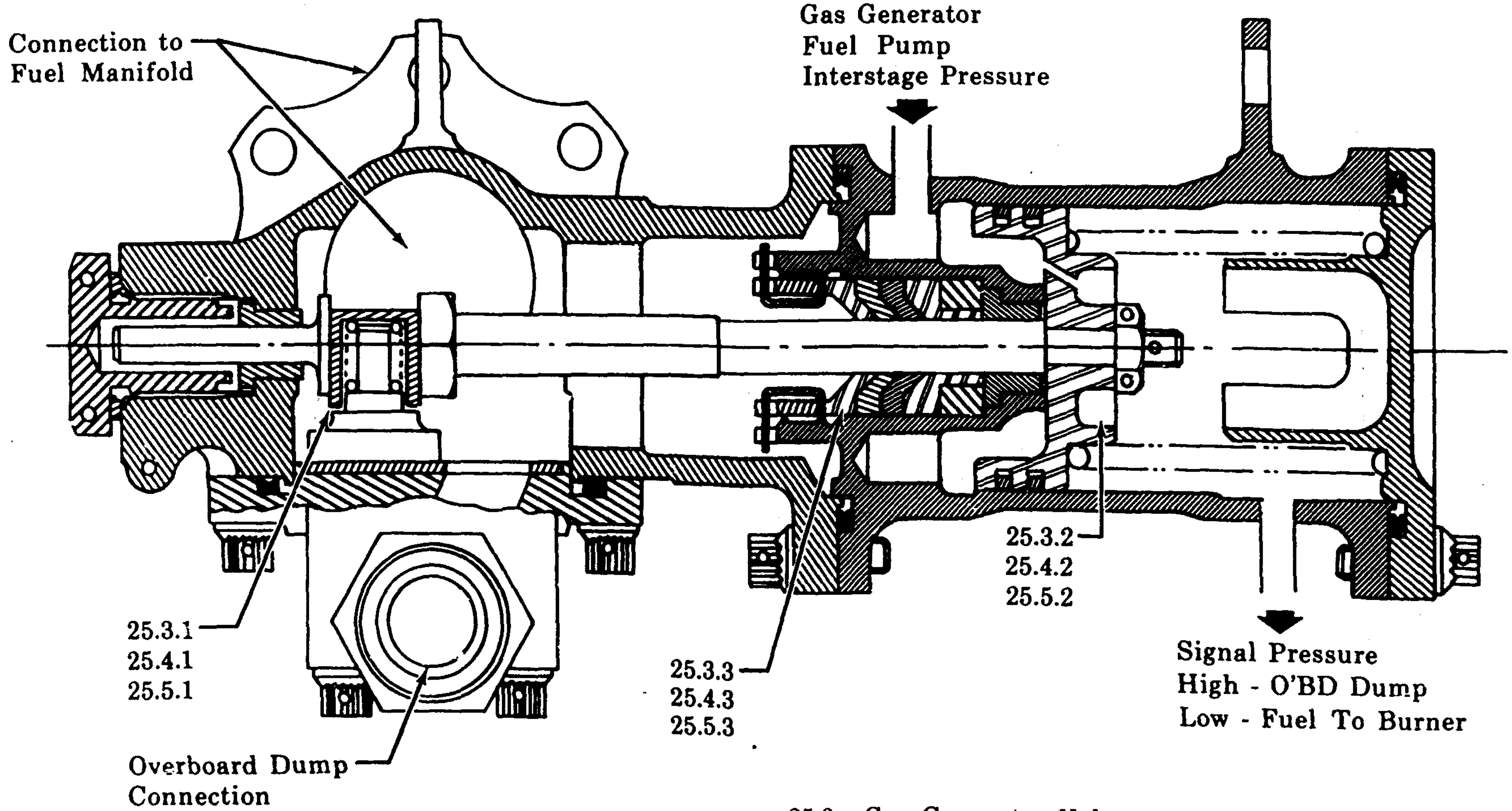
Fuel Manifold Drain Valve - Cross Section



25.3 - Gas Generator Valve
25.4 - Duct Heater Zone I Valve
25.5 - Duct Heater Zone II Valve

FD 14829A

25.6 DUCT HEATER FUEL PUMP

A. Description

The duct heater fuel pump supplies fuel, through the unitized fuel control and the fuel injection system, to the duct heater combustor where it is burned to produce thrust augmentation. The pump assembly consists of an inducer boosted centrifugal pumping element which is driven by an axial flow air turbine. Use of this variable speed capability permits operation of the pump at reduced speed for most of the flight regime. The speed is modulated to produce only the pressure rise necessary to provide the duct heater fuel flow required for the specific altitude and Mach number conditions.

Turbine drive air is supplied from the compressor discharge bleed manifold and is regulated by a duct pump controller. This controller varies pump speed as required to produce only the output pressure demanded by the fuel control. The pump controller is described as part of the unitized control.

Overspeed protection is provided by a vortex venturi at the turbine discharge. This device, which does not require moving parts or a pump speed sensor, aerodynamically limits pump overspeed by creating a back pressure at the turbine discharge if an overspeed condition develops, thereby reducing the available turbine horsepower. Increased turbine discharge swirl angle associated with overspeed initiates a vortex which produces an aerodynamic restriction to turbine discharge airflow.

The centrifugal pumping element is driven directly by the turbine through an interconnecting shaft. Fuel is force fed into the impeller by an inducer located upstream in the fuel inlet housing. The inducer is driven at one-sixth of turbine speed by a planetary geared drive. The low-speed inducer provides excellent pumping characteristics at very low fuel inlet pressure levels.

Fuel is used to lubricate and cool the bearings, seals and inducer spee reduction gears. This feature eliminates the need for an external oil supp and scavenge system, and also precludes the possibility of depleting or diluting the engine oil supply in the event of turbine end or impeller end shaft seal failures.

A cross section of the pump is presented following the analysis of the pump.

JTF17 FAILURE MODE & EFFECT ANALYSIS

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Sheet I
B. ANALYSIS
25.6 Duct Heater Fuel Pump

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Bearings (3) 25.6.1.	Support Main Pumping Shaft	Seizure	SLTO: Pump may seize due to bearing failure resulting in loss of duct heater fuel flow. Pump controller will schedule pump turbine air supply control valve to full open position.	If pump seizes, loss of duct heater fuel flow	If pump seizes, duct heater will flame out and augmentation will be lost due to loss of fuel flow. Engine bleed air to pump turbine will be increased due to full open position of air control valve $F_n = 60\% F_{nma}$	If pump seizes, AF and CR	If pump seizes, reduce to and/or maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except $F_n = 20\% F_{nma}$ In addition oil temperature will increase and may eventually exceed limits due to loss of duct heater oil cooler fuel flow	Same as SLTO Also may have IFS	If pump seizes, reduce to and maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions. Monitor engine oil temperature. If necessary to maintain oil temperature limit, reduce aircraft speed to subsonic conditions.
			Landing: Not affected. If pump seizes, duct heater fuel flow not available	Not affected	Not Affected. If pump seizes, maximum available F_n limited to SLTO conditions.	Same as SLTO	None If pump seizes and maximum F_n desired, same as SLTO.
Fuel Seal 25.6.2	Seals Turbine end of Main Pumping Shaft	Bellows Failure	SLTO: Performance not affected. There will be a loss of fuel through the overboard drain. Maximum fuel loss approximately 100 pph.	Excessive overboard drain fuel leakage.	Not affected.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Not affected.	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Not affected.	Same as SLTO	None
Metering Orifice 25.6.3	Meters Fuel supply to bearings for lubrication and cooling	Contamination	SLTO: Possibility of contamination remote because orifice is protected. If contamination occurs to the extent that complete fuel flow loss occurs, bearings will eventually fail and pump may seize resulting in loss of duct heater fuel flow. Pump controller will schedule pump turbine air supply control valve to full open position.	If pump seizes, loss of duct heater fuel flow	If pump seizes, duct heater will flame out and augmentation will be lost due to loss of fuel flow. Engine bleed air to pump turbine will be increased due to full open position of air control valve. $F_n = 60\% F_{nma}$	If pump seizes, AF and CR	If pump seizes, reduce to and/or maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet I

No. 2 of 2

Duct Heater Fuel Pump (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Metering Orifice 25.6.3 (Cont.)			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except F_n = 20% $F_{n_{max}}$. In addition oil temperature will increase and may eventually exceed limits due to loss of duct heater oil cooler fuel flow.	Same as SLTO Also may have IFS	If pump seizes, reduce to and maintain non-augmented PLA range. Adjust F_n level on unaffected engines to obtain desired aircraft conditions. Monitor engine oil temperature. If necessary to maintain oil temperature limit, reduce aircraft speed to subsonic conditions.
			Landing: Not Affected. If pump seizes, duct heater fuel flow not available.	Same as SLTO	Not affected. If pump seizes, maximum available. F_n limited to SLTO conditions.	Same as SLTO	None If pump seizes and maximum F_n desired, same as SLTO.
Splined Connector 25.6.4	Connects Inducer Shaft to Main Shaft	Shear	SLTO: Inducer becomes inoperative. The main stage will continue to operate.	None	Not affected as long as aircraft boost pumps operate.	Not Affected.	None
			Cruise: Same as SLTO	None	Same as SLTO	Not Affected.	None
			Landing: Same as SLTO	None	Not Affected. Maximum F_n is available as long as aircraft boost pumps operate.	Not Affected.	None
Bearing (4 Antifriction) (3 Sleeve) 25.6.5	Support Inducer	Seizure	SLTO: Inducer drive will shear and inducer becomes inoperative. The main stage will continue to operate.	None	Not affected as long as aircraft boost pumps operate.	Not Affected.	None
			Cruise: Same as SLTO	None	Same as SLTO	Not Affected.	None
			Landing: Same as SLTO	None	Not Affected. Maximum F_n is available as long as aircraft boost pumps operate.	Not Affected.	None
Gear Train 25.6.6	Reduces Inducer speed relative to pump speed.	Failure resulting in seizure of inducer	SLTO: Inducer becomes inoperative. The main stage will continue to operate.	None	Not affected as long as aircraft boost pumps operate..	Not Affected.	None
			Cruise: Same as SLTO	None	Same as SLTO	Not Affected.	None
			Landing: Same as SLTO	None	Not Affected. Maximum F_n is available as long as aircraft boost pumps operate.	Not Affected.	None

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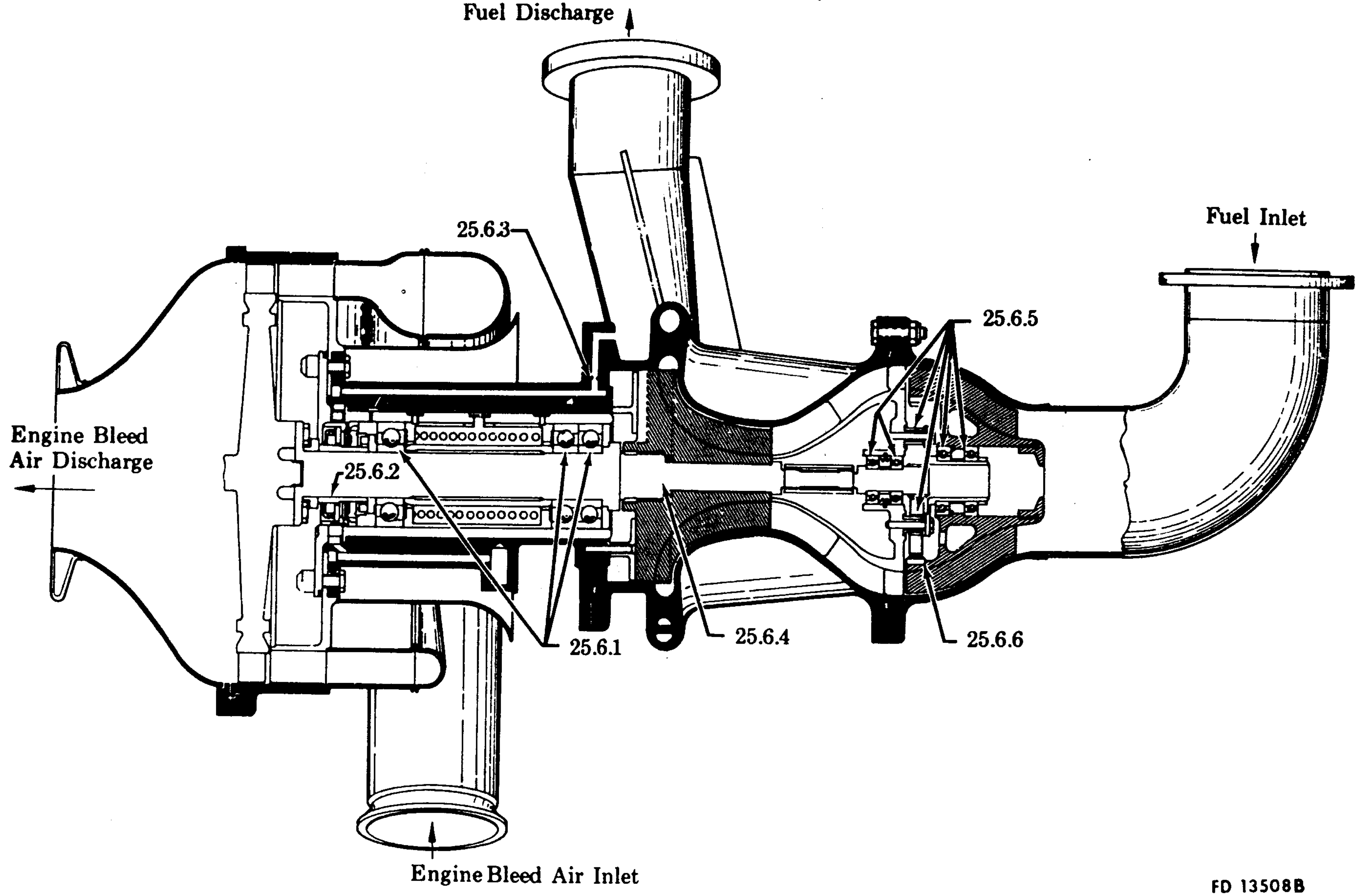
Duct Fuel Pump



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25.7 HYDRAULIC PUMP

A. Description

The hydraulic pump is an engine driven, reciprocating multiple piston fuel pump that is utilized to provide the engine hydraulic system with fuel at the required flow rates with a pressure rise across the pump of 1500 psi.

Integrator and proportional servo valves control the pump cam plate to maintain a constant 1500-psi pump discharge pressure. The variation in hydraulic fuel flow necessary to position and control the duct nozzle area and the reverser-suppressor is met by varying the stroke of the pump pistons.

Two rotors are driven and supported by a common shaft, each having nine equally spaced pistons, and reciprocated by a common nonrotating cam plate through piston shoes. Auxiliary cam plates, which are loaded by rotor springs, hold the piston shoes against the cam plate at all times, assisting return of the pistons during the suction strokes. The geometry of the spherical cam plate face and convergent piston axes significantly reduces the side loading applied to the pistons when they are in the extreme retracted position. This design feature also takes advantage of centrifugal force to help retract the pistons and minimizes the pump volume by reducing the diameter of the valving interface.

The cam plate angle controls the displacement capacity of the pump. The cam plate is supported by two trunnion bearings on an axis, which is located on a diameter of the cam plate. A shimmed stop screw limits the maximum cam plate angle to provide the desired maximum piston displacement.

Variable delivery at constant pressure is provided by controlling the cam plate angle with two concentric actuator pistons which act in opposition to a return spring. The spring drives the cam plate toward full stroke and provides the required rapid response to demands for increased fuel flow rate. The pistons respond to pump output pressure level as sensed by their respective control valves. The two control valves provide integral and proportional control for stable dynamic pump response throughout the required operating regime of this application.

Each of the sensing control valves modulates the pressure to its actuator piston. The physical arrangement of the actuator pistons provides a "summing" action without structural linkages.

The inner piston is controlled in virtually an integral action. The control valve is nulled by only the balance of an adjustable reference spring and the reaction of pump delivery pressure on the end of the valve.

The outer actuator piston is controlled in a similar manner, but in a proportional action. This control valve senses piston position through a feedback spring as well as delivery pressure and a reference spring force.

The combined action of these servocircuits is proportional in any transient, except at equilibrium.

Sealing and valving of the main flows of the pump are provided by ported insert plates located at the face of each rotor.

Hydraulic pump discharge fuel flows through an integral, 10-micron full-flow filter, with a differential pressure actuated bypass, which relieves if the pressure drop through the filter exceeds 20 psi.

The external drive spline is forced oil lubricated by the engine oil lubrication system.

A cross section of the pump is presented following the analysis of the pump.

JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet 1 No.___of___

B. ANALYSIS
25.7 Hydraulic Pump

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Rotor Shaft Bearings (2) 25.7.1 or Cam Plate Shoe Retainer Bearings (2) 25.7.2	Support rotating rotor shaft. Retention of cam plate shoe retainer and bearing surface for the retainer during cam plate angle changes.	Bearing failure	SLTO: Will cause pumping failure resulting in complete loss of hydraulic pressure. Duct nozzle goes to open position.	Duct nozzle to open position.	N_1 higher than normal. F_n = 90% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO except F_n = 85% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Same as SLTO In addition, reverser-suppressor actuation not available.	Same as SLTO In addition, reverser-suppressor cannot be actuated.	Some reduction in F_n. N_1 higher than normal. Reverse F_n not available. If maximum F_n desired, same as SLTO.	Same as SLTO	Adjust PLA to obtain desired landing F_n. If reverse F_n desired, retard PLA to idle and adjust F_n level on unaffected engines to obtain desired aircraft conditions. If maximum F_n desired, same as SLTO.
Pistons (18) 25.7.3	Pumping elements to provide high pressure hydraulic fuel.	Single piston seizure in bore.	SLTO: Piston shoe disengages from shoe retainer. Steady-state pump performance not affected. During transient operation (actuator displacement) maximum pump capacity reduced approximately 5% resulting in decrease in actuator system response. May result in subsequent hydraulic pump deterioration.	Duct nozzle operation may be slower than normal.	Duct nozzle operation may be slower than normal.	CR	Slower than normal PLA movements, particularly during duct burner operation, will assist the hydraulic pump in meeting demand requirements.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO Movement of reverser-suppressor may be slower than normal.	Same as SLTO Movement of reverser-suppressor may be slower than normal.	Same as SLTO	Same as SLTO
Proportional Pilot Valve 25.7.4 or Proportional Actuator 25.7.5	Controls proportional actuator to provide fast pump response for large hydraulic system demands. Provides fast positioning of the cam plate actuator for fast pump response to large hydraulic system demands.	Seizure	SLTO: Steady-state and slow transient conditions of hydraulic system are not appreciably affected. Fast transient response is decreased.	Duct nozzle operation may be slower than normal and may tend to fluctuate.	Duct nozzle operation may be slower than normal and may tend to fluctuate.	CR	Slower than normal PLA movement, particularly during duct heater operation, will assist the hydraulic pump in meeting demand requirements.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO Movement of reverser-suppressor may be slower than normal.	Same as SLTO Movement of reverser-suppressor may be slower than normal.	Same as SLTO Movement of reverser-suppressor may be slower than normal.	Same as SLTO	Same as SLTO

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JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet I — No.___ of___

Hydraulic Pump (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Integral Pilot Valve 25.7.6	Control the cam plate actuator to maintain a constant pump pressure rise.	Seizure	SLTO: Hydraulic pressure regulation is accomplished by proportional system and pressure will tend to fluctuate.	Duct nozzle will tend to fluctuate.	Duct nozzle will tend to fluctuate.	CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
Cam Plate 25.7.7 or Cam Plate Actuator Piston 25.7.8	Variable angle fixed table that provides piston reciprocation as the piston rotors rotate. Positions cam plate to maintain flow and pressure at demand level.	a) Seizure (low flow steady-state position.	SLTO: Hydraulic pressure level may increase and fluctuate during steady-state conditions. For transient conditions, pump will not be able to respond to increased flow demand resulting in pressure level decrease followed by slow recovery.	Duct nozzle movement may be slower than normal and may fluctuate.	Duct nozzle movement may be slower than normal and may fluctuate. Some airflow error suppression during duct nozzle transient of initiating duct heating.	CR	Slower than normal PLA movements, particularly during duct heater operation, will assist the hydraulic pump in meeting demand requirements.
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO
			Landing: Same as SLTO Movement of reverser-suppressor will be slower than normal.	Same as SLTO Movement of reverser-suppressor will be slower than normal.	Same as SLTO Movement of reverser-suppressor will be slower than normal.	Same as SLTO	as SLTO
		b) Seizure (high flow transient position)	SLTO: Hydraulic pump discharge pressure increases until overpressure system activates resulting in loss of hydraulic pressure. Duct nozzle goes to open position.	Duct nozzle to open position.	F_n = 90% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Cruise: Same as SLTO	Same as SLTO	F_n = 85% F_{nma}	Same as SLTO	Same as SLTO
			Landing: Same as SLTO In addition, reverser-suppressor actuation not available.	Same as SLTO In addition, reverser-suppressor cannot be actuated.	Some reduction in F_n. N_1 higher than normal. Reverse F_n not available. If maximum F_n desired, same as SLTO.	Same as SLTO	Adjust PLA to obtain desired landing F_n. If reverse F_n desired, retard PLA to idle and adjust F_n level on unaffected engines to obtain desired aircraft conditions. If maximum F_n desired, same as SLTO.

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JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet I

No.__ of____

Hydraulic Pump (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Hydraulic Pump Discharge 10 Micron Filter 21.7.9	Contamination protection. Filters hydraulic pump discharge fuel flow.	Excessive contamination deposited in filter.	SLTO: When fuel pressure drop across the filter exceeds a preset level, the filter bypass valve opens allowing fuel to bypass the filter. This permits contaminate to enter the hydraulic system and the return to gas generator pump interstage. May eventually cause hydraulic pump, gas generator pump, and control system deterioration depending on the contaminate.	None. Excessive contaminant in the filter and corrective action can be controlled in most instances by normal periodic inspection and maintenance.	No immediate effect	No immediate effect	None.
			Cruise: Same as SLTO	None	No immediate effect	No immediate effect	Same as SLTO
			Landing: Same as SLTO	None	No immediate effect	No immediate effect	Same as SLTO

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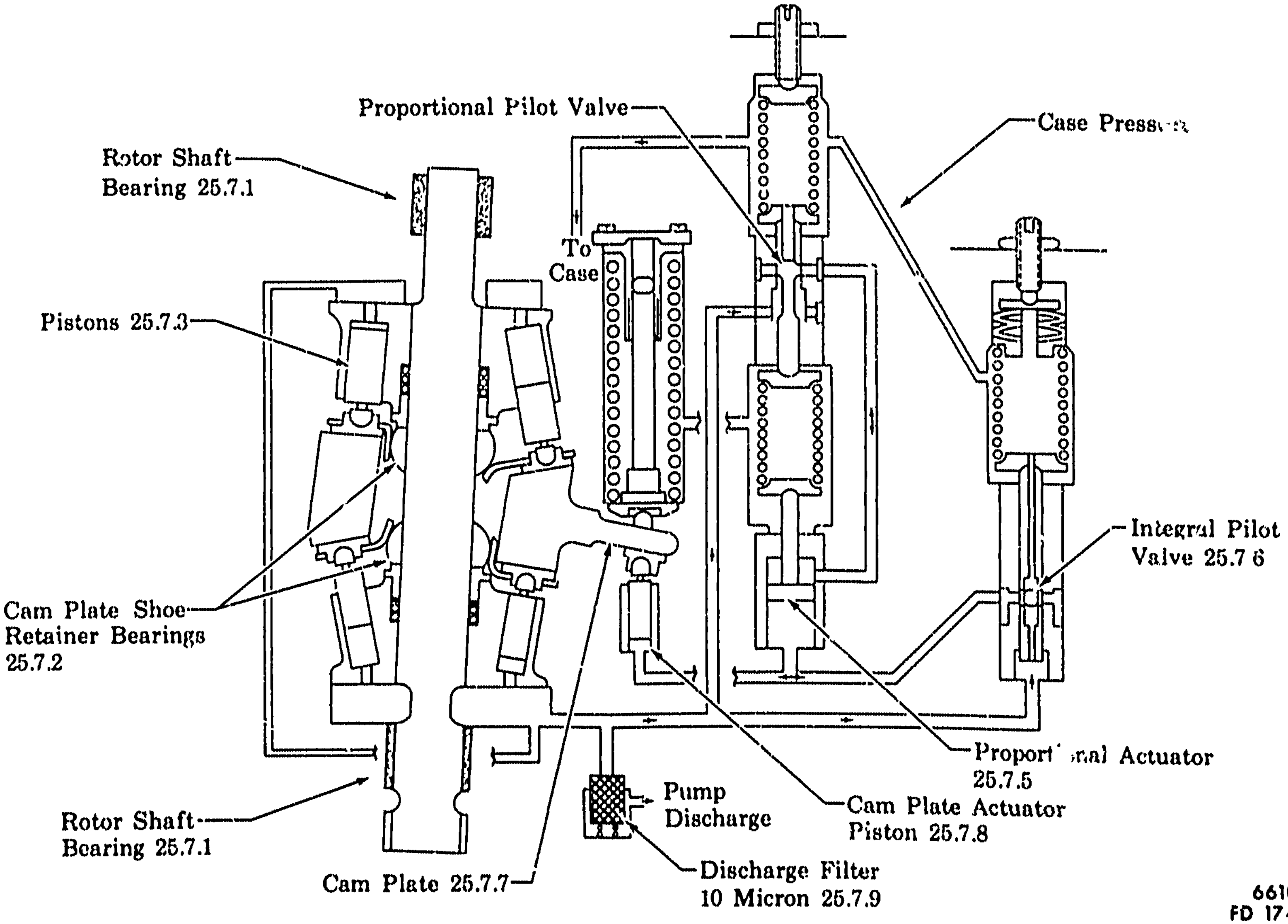
Hydraulic Pump Schematic



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25.8, 25.9, and 25.10 ELECTRICAL IGNITION SYSTEM

A. Description

The JTF17 ignition system is composed of two fuel-cooled 400-cycle-per-second alternating current powered exciters and four shunted surface gap igniters electrically connected to the exciters by flexibly shielded low-tension electrical cables. Each of the exciters contains two capacitance discharge type independent electrical circuits. Each circuit produces a 4-joule, 3000-volt electrical output to fire the igniter. A flight crew activated circuit in each exciter fires a gas generator igniter while its associated twin is automatically activated for approximately 16 seconds by the unitized control upon augmentation selection to fire a duct heater igniter. To extend the useful service life of the igniters, an inductance type voltage booster is incorporated into each circuit just prior to the exciter discharge. The igniter electrodes and igniter gap shunt material will erode to some degree after extended service causing an air gap to be created between the electrodes and the shunting material. An increased voltage is then required to ionize the air in the gap to fire the igniter. Under this condition, the exciter voltage output is increased by the voltage booster as required to fire the igniter up to 6000 volts maximum, thereby considerably increasing igniter life.

Also included in each exciter circuit is a voltage signal generator which produces a signal voltage whenever the exciter delivers an output electrical discharge to the igniter. The electrical signal indicates that the exciter is transmitting spark electrical energy to the igniter and is provided for monitor and checkout purposes. A separate aircraft switch is required to check out the duct heater ignition system at altitude conditions prior to descent. A power lever switch in the unitized control limits such checkouts to minimum nonaugmented operation. Gas generater ignition system checkout at altitude is accomplished using the aircraft ignition-on switches.

An electrical system block diagram, exciter wiring schematic diagram, and cross section of the gas generator and duct heater igniters are presented following the analysis of the electrical ignition system.

Sheet 1
B. ANALYSIS
Electrical Ignition System

JTF17 FAILURE MODE & EFFECT ANALYSIS

No. 4

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Exciters (2) 25.8	Each exciter changes aircraft electrical supply power to a condition suitable to provide spark discharge for ignition purposes. Each exciter supplies spark ignition energy to one gas generator igniter and one duct heater igniter.	Any failure resulting in lack of spark discharge at an igniter.	SLTO: Not affected. Redundant exciter and igniter systems provided.	A voltage signal generator is provided in each exciter to check the gas generator and duct heater circuit.	Not affected. Relight capability of gas generator and duct heater assured by redundant system.	Not affected. If an exciter, igniter, or lead fails: CR	None
			Cruise: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
			Landing: Same as SLTO	Same as SLTO	Same as SLTO	Same as SLTO	None
or							
Gas Generator Igniter (2) 25.9	Each igniter receives electrical energy from its exciter for spark discharge ignition of the gas generator.						
or							
Duct Heater Igniter (2) 25.10	Each igniter receives electrical energy from its exciter for spark discharge ignition of the duct heater.						
or							
High Tension Leads a) Exciters to Gas Generator Igniters (2 Leads) 25.11 b) Exciters to Duct Heater Igniters (2 Leads) 25.12	Electrical cables used to conduct the discharge energy from the exciters to the igniters.						

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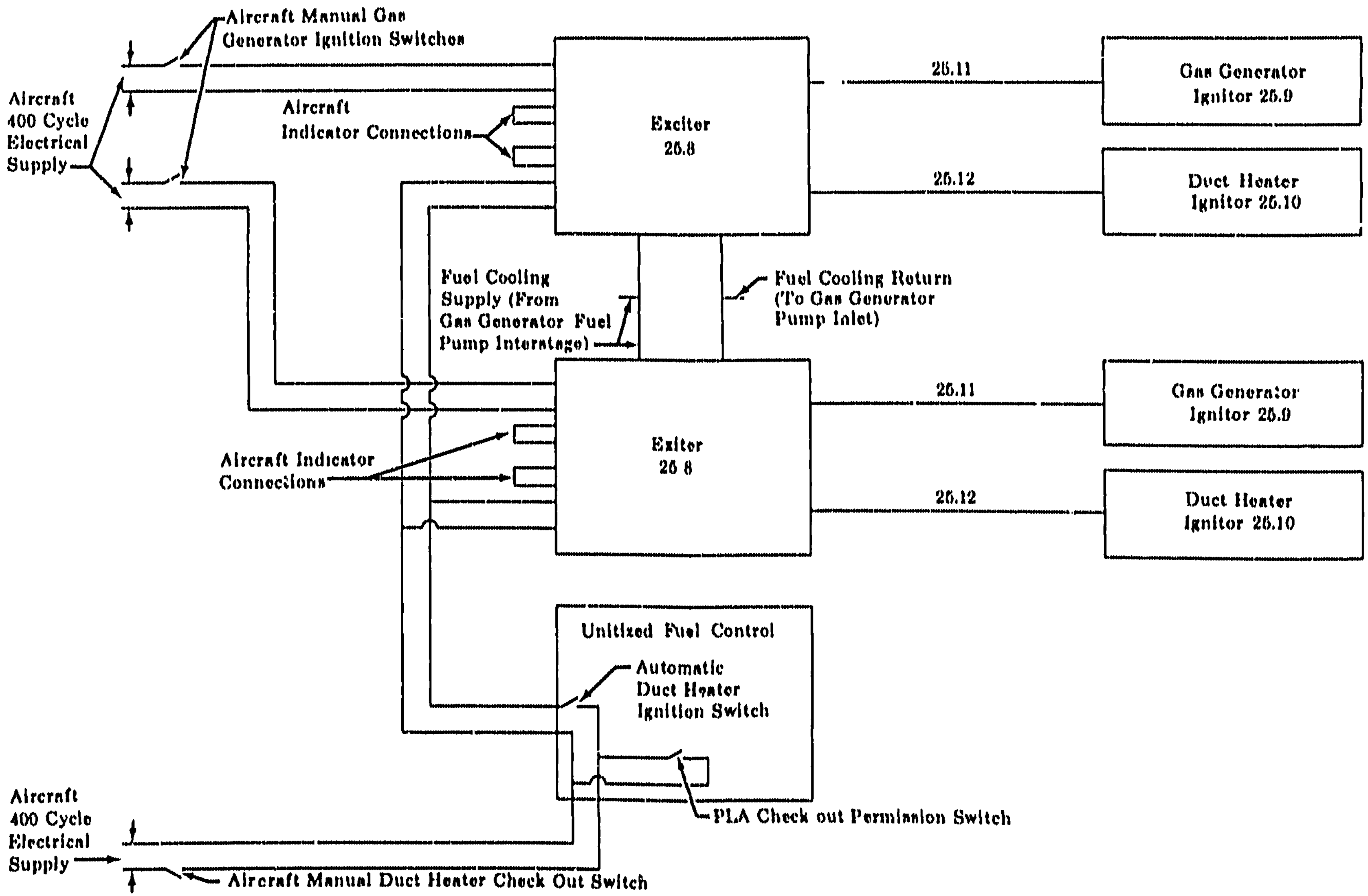
Electrical Ignition System Schematic Block Diagram



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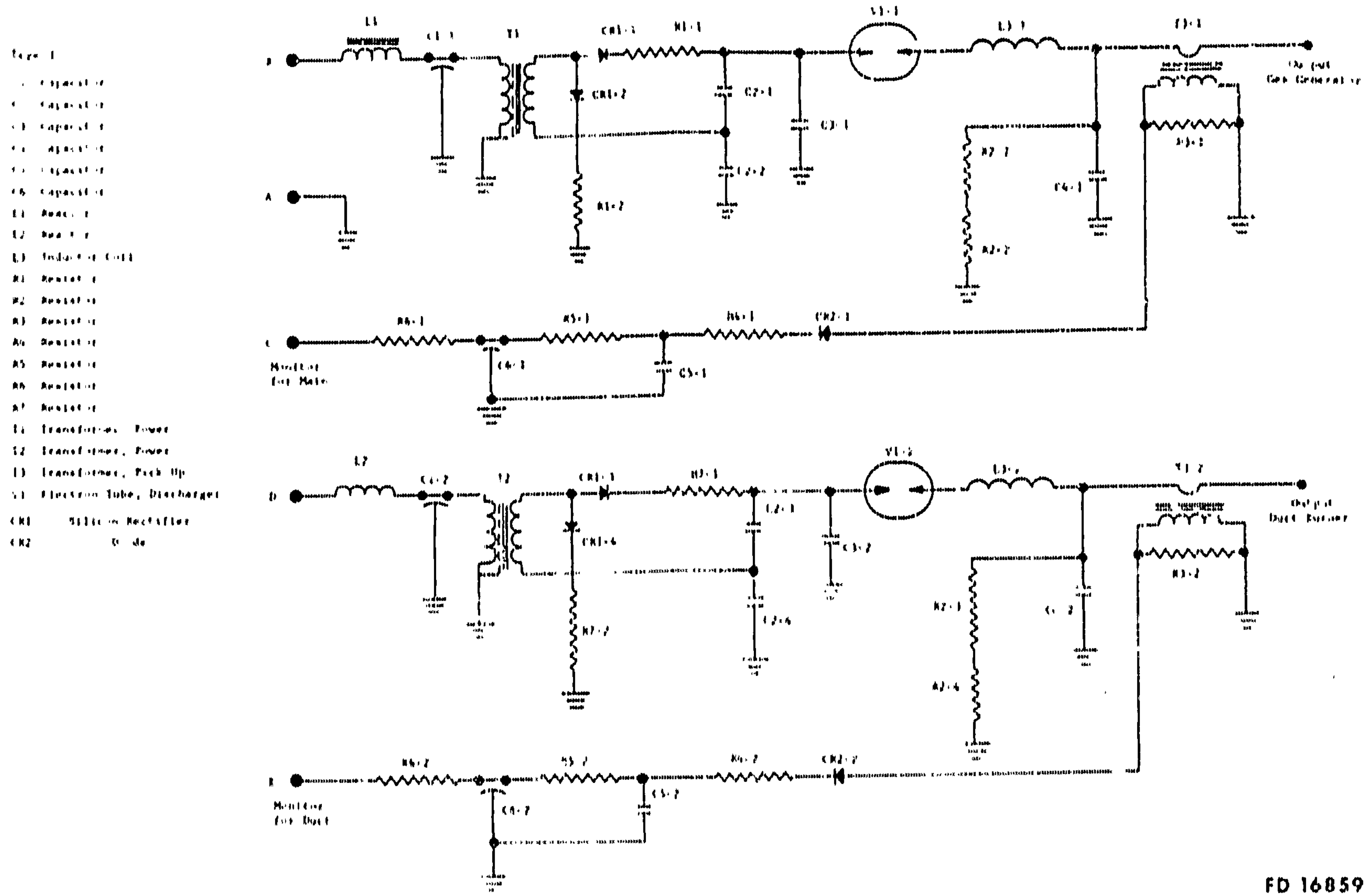
GLA Ignition Exciter Wiring Diagram



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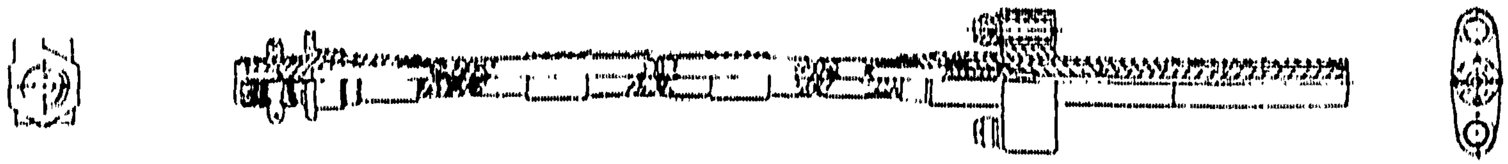
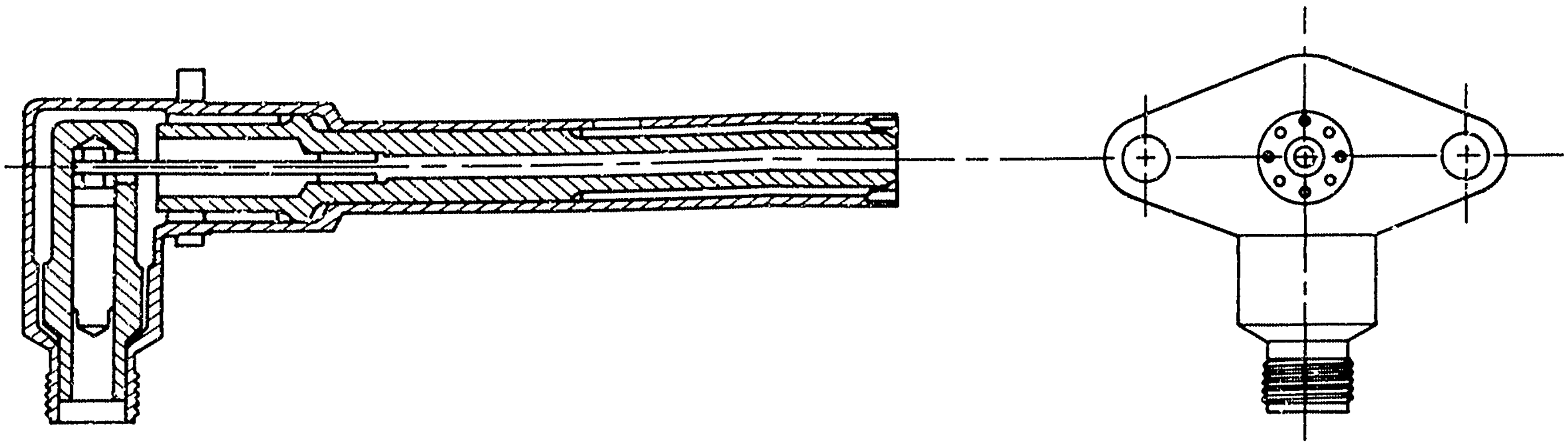
Gas Generator Igniter Assembly



Identification Marking
Champion FHE 209-1
PWA 2121798

FD 16623

Duct Heater Igniter Assembly



Identification Marking

Champion FHE 210-1

PWA 2117800

FD17159

INTRODUCTION

The JTF17 Failure Modes and Effects Analysis study contained in P&WA report PDS 2025 did not include the control of the secondary air system required for the Boeing installation. This appendix contains revised portions where applicable and supplementary information to reflect incorporation of the secondary air control system within the unitized control.

A fold-out schematic is located at the end of this appendix so that by prior exposure it may be left in view while reading the appendix.

JTF17 FAILURE MODE & EFFECT ANALYSIS

Sheet 1 — No. __ of __

Component Sense or Signal Failures

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
The following is in addition to Section I, Component Sense or Signal Failures, of P&WA Report PDS-2025.							
24. Secondary Airflow Control Signals							
a. Positioning Fuel Pressure Signals from Unitized Control	Two signals from unitized control. One signal positions two bypass duct butterfly valves as a function of T_{T2} and the other signal positions two bypass duct butterfly valves as a function of SOL position as authorized by PLA. Both systems control butterfly valve position using high pressure to close and low pressure to open.	Loss of pressure or loss of high pressure capability of T_{T2} controlled signal.	SLTO: Not affected. On climb, the T_{T2} controlled bypass duct valves remain open instead of closing at approximately 240°F T_{T2}.	None Position indicator will show valves open above 240°F T_{T2}	Not affected Not affected	Not affected Inlet-engine airflow match will be less than optimum with some loss in performance.	None Adjust engine airflow to obtain desired airflow match.
			Cruise: The T_{T2} controlled bypass duct valves open.	Position indicator will show valves open.	Not affected	Inlet-engine airflow match will be less than optimum with some loss in performance	Adjust engine airflow to obtain desired airflow match
			Landing: Not affected	None	Not affected	Not affected	None
		Loss of pressure or loss of high pressure capability of SOL controlled signal.	SLTO: Not affected	None	Not affected	Not affected	None
			Cruise: The SOL controlled bypass valves open if closed or cannot be closed if open.	Position indicator will show valves open.	Not affected	Inlet-engine airflow match will be less than optimum with some loss in performance.	Adjust engine airflow to obtain desired airflow match.
			Landing: Not affected	None	Not affected	Not affected	None
b. Gas Generator Pump Interstage Pressure	Provides force to open the four bypass duct butterfly valves when positioning signals are at low pressure.	Loss of pressure	SLTO: The four bypass duct valves close.	Position indicator will show valves closed	Not affected During high Mach number portion of supersonic climb, maximum augmentation will result in over-temperature of the engine ejector which will shorten its life.	Not affected During supersonic climb, inlet-engine airflow match will be less than optimum with some loss in performance.	None Adjust engine airflow to obtain desired airflow match. Use 80% augmentation or less during supersonic climb.
			Cruise: Not affected	None	Not affected. Maximum augmentation will result in over-temperature of the engine ejector which will shorten its life.	None	Use 80% augmentation or less.
			During descent, two bypass valves will not open with SOL and two bypass valves will not open when T_{T2} is below approximately 240°F.	Position indicator will show valves remain closed.	Not affected	Inlet-engine airflow match will be less than optimum with some loss in performance.	Adjust engine airflow to obtain desired airflow match.
			Landing: Same as SLTO	Same as SLTO	Not affected	Not affected	None

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The following is an addition to Section II, 25.2A, Unitized Control Description.

SECONDARY AIRFLOW CONTROL SYSTEM

The secondary airflow control system is an integral part of the unitized fuel and area control which controls the secondary airflow bypassed through the ducts from the engine inlet to the ejector as a function of power lever angle, shutoff lever position and compressor inlet temperature.

The secondary air bypass system consists of six ducts, each of which has a check valve to prevent reverse airflow, and four of the ducts incorporate butterfly valves which are positioned by two-position actuators. A valve which is positioned by the T_{t2} servo in the unitized fuel control, ports gas generator control fuel inlet pressure to two of the actuators to close two bypass ducts when compressor inlet temperature exceeds 240°F (Mach 2.0). Closing these ducts improves performance during the climb portion of the flight envelope.

Aircraft crew advancing of the shutoff lever sequencing valve in the unitized fuel control ports gas generator control inlet pressure to two actuators to close two other bypass ducts when cruise conditions are reached in order to optimize engine performance. This signal is interlocked with the power lever sequencing valve which prevents closing these two ducts whenever engine power is in excess of 80% of maximum augmented thrust. The interlock prevents inadvertent closing of the bypass ducts during augmentation conditions at high Mach number which would overtemperature the ejector.

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Unitized Control

The following are revisions to Section II 25.2 Unitized Control Analysis of P&WA Report PDS 2025 and replace the applicable portions of the report.

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Shutoff Lever Sequencing Valve 25.2.1.1.	Provides arming and signaling for all shut-off valve functions. Also provides signal to position two secondary air bypass duct valves as authorized by PLA.	Seizure	SLTO: Not Affected	None	Not Affected	Not Affected	None
			Cruise: Not affected. Control of the SOL bypass duct valves is maintained due to mechanical connection of sequencing valve. SOL torque will increase.	SOL torque increase to close bypass duct valves.	Not Affected	Not Affected	None
			Landing: Not Affected. Engine can be shutoff with SOL due to mechanical connection of sequencing valve. SOL torque will increase.	SOL torque increase to shutoff engine.	Not Affected	Not Affected	None
Power Lever Boost and Sequencing System 25.2.2.	Provides with minimum input torque, control of gas generator speed and power level and control of augmentation. Also provides sequencing of reverser suppressor and authorization of SOL controlled secondary air bypass duct positioning.						
Power Lever Boost Power Piston 25.2.2.2.	Provides power boosted rotation of PLA cam shaft in response to PLA input through control valve.	Seizure	SLTO: Control system remains at setting existing at time of failure. T_{t2} bias of schedule will continue to function.	No control of engine power setting.	Engine power remains at setting existing at time of failure. T_{t2} bias of power setting continues to function.	OK. If additional power desired, AF.	None at conditions existing at time of failure. If power change desired, adjust I_n level on unaffected engines to obtain desired aircraft conditions. Engine can be shutdown with SOL.
			Cruise: Same as SLTO. In addition, the SOL controlled secondary air bypass duct valves cannot be closed at cruise if seizure occurs at power setting above 80% maximum augmented.	Same as SLTO. Position indicator will show bypass duct valves open.	Same as SLTO. Not affected.	Same as SLTO. Inlet engine airflow match will be less than optimum with some loss in performance.	Same as SLTO. Adjust engine airflow to obtain desired airflow.
			Landing: Same as SLTO. In addition, reverser-suppressor actuation not available.	Same as SLTO	Same as SLTO. In addition, reverse thrust not available.	Same as SLTO	Same as SLTO

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Unified Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
PLA sequencing Valve (5.2.1).	Provides sequencing of reverser-suppressor, and duct heater initiation with authority of low speed protection valve. Also sequences duct heater zone transfer and authority for SOL to close secondary air bypass duct valves.	a) Seizure in zone transfer position	SLTO: Control system not affected at PLA setting at time of failure (zone transfer) and higher.	None	Not Affected	None	None
			As PLA is reduced below zone transfer, Zone II fuel flow continues and lowers Zone I fuel flow below normal. On subsequent PLA advance to zone transfer or higher, the normal airflow bias signal to the total airflow reset piston will not occur.	Normal engine total airflow decrease during zone transfer will not occur.	As PLA reduced, eventual Zone II flameout. Zone I fuel flow lower than normal with F_n lower than normal. Readvancing PLA will result in restoring Zone II augmentation before zone transfer PLA position.	CR	Advance PLA to near zone transfer or higher to restore normal augmentation. Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			Duct heater fuel flow cannot be shutoff with PLA until PLA reduction results in approximately 80% N_2 or lower. Subsequent N_2 increase above 80% will reinitiate duct heater fuel flow.	Duct heater cannot be shutoff with normal reduction to maximum nonaugmented position.	Duct heater fuel shutoff requires reduction to 80% N_2 or lower. Subsequent increase in N_2 above 80% will reinitiate duct heater.	Same as above	If duct heater shutoff desired, reduce N_2 with PLA.
			Cruise: Same as SLTO In addition, SOL controlled secondary air bypass duct valves cannot be closed if seizure occurs at power setting above 80% maximum augmented.	Same as SLTO Position indicator will show SOL controlled bypass duct valves open.	Same as SLTO Not Affected	Same as SLTO Inlet-engine airflow match will be less than optimum with some loss in performance.	Same as SLTO Adjust engine airflow to obtain desired airflow match.
			Landing: Not applicable. If duct heater initiated and failure occurs, same as SLTO. In addition cannot actuate reverser-suppressor.	Not Applicable	Not Applicable. If duct heater initiated and failure occurs, same as SLTO. In addition, reverse F_n not available.	Not Applicable	None If duct heater initiated and failure occurs, same as SLTO.
		b) Seizure in any position other than (a) above.	For seizure in any position (other than in zone transfer position described above), PLA authority will be maintained in an increasing direction due to PLA boost system and mechanical override driving the sequencing valve in an increasing direction. For seizure up to a maximum nonaugmented PLA position, the only effect will be the inability to obtain reverse thrust. For seizure in the Zone I augmented range, the analysis of (a) above will apply except PLA reduction below zone transfer is not applicable and the secondary air bypass duct valves can be closed at cruise providing PLA is not advanced to 80% power setting or higher.				
Compressor Inlet Temperature Sensing System (2 Sensors Remote Mounted) (5.2.3).	Senses compressor inlet temperature (T_{t2}) with dual remote mounted sensors and utilizes the sense to provide T_{t2} bias of various cams and control positioning of two secondary air bypass duct valves.						

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
Remote T_{t2} sensor flapper valve 25.2.1.5 or Remote T_{t2} sensor motor bellows 25.2.3.2	Controlled by the gas filled bulb and bellows to provide a modulated fuel pressure signal to the control as a function of T_{t2}. Transmits gas filled bulb pressure level to remote sensor flapper valve.	Contamination (closed position) / Loss of gas charge (gas section of bellows and bulb fills with servo fuel).	SLTO: Control T_{t2} system at maximum hot T_{t2} position. Gas generator fuel flow, duct heater fuel flow, duct nozzle, compressor bleeds, compressor inlet guide vanes, and T_{t2} controlled secondary air bypass duct valves scheduled to maximum hot T_{t2} position. Duct heater fuel flow response rate with PLA is constant at approximately cruise response rate.				
or T_{t2} pilot valve 25.2.3.9	Modulates T_{t2} servo piston as a function of T_{t2} (remote sensor signal).	Seizure (High T_{t2} position)	During augmentation, duct nozzle scheduled to full open position. Compressor bleeds open. Compressor inlet guide vanes to start-cruise position. T_{t2} controlled secondary air bypass duct valves close. Gas generator and duct heater fuel flows decreased.	Duct nozzle full open. Gas generator fuel flow, duct heater fuel flow, N_2, T_{t7}, and EPR lower than normal. Position indicator will show T_{t2} controlled bypass duct valves closed.	F_n = 30% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			During nonaugmentation, same as above except duct nozzle scheduled to 4.5 square feet position.	Same as above except duct nozzle at 4.5 square feet position.	F_n = 25% F_{nma} Augmentation may be initiated and F_n increased to value above.	Same as above	Reinitiate augmentation if additional F_n desired.
			Cruise: During augmentation, duct nozzle area larger than normal, gas generator and duct heater fuel flows lower than normal.	Duct nozzle area larger than normal. Gas generator fuel flow, duct heater, fuel flow, N_2, T_{t7}, and EPR lower than normal.	F_n = 85% F_{nma}	Same as SLTO	Same as SLTO
			During nonaugmentation, same as above except duct nozzle scheduled to 4.5 square feet position.	Same as above except duct nozzle at 4.5 square feet position.	F_n = 15% F_{nma} Augmentation may be initiated and F_n increased to value above.	Same as SLTO	Same as SLTO
			During descent, compressor bleeds open and compressor inlet guide vanes remain in start-cruise position. Also, T_{t2} controlled secondary air bypass duct valves remain closed when T_{t2} if reduced below 240°F.	Same as above. Also, position indicator show T_{t2} controlled bypass duct valves closed below 240°F T_{t2}.	Power schedules do not follow normal T_{t2} bias as conditions change.	Same as SLTO. Also, inlet-engine airflow match will be less than optimum.	Modulate PLA to obtain desired descent conditions.
			Landing: Same as SLTO	Same as SLTO	Some F_n change. If maximum F_n desired, same as SLTO.	Same as SLTO	Adjust F_n level with PLA. If maximum F_n desired, same as SLTO.

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[illegible] Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
T_{t2} Pilot Valve [illegible] 3.9 or T_{t2} Receiver Bellows [illegible] 2.3.8	See previous functional description Transmits remote sensor modulated pressure signal force to T_{t2} pilot valve.	Seizure (low T_{t2} position) Bellows failure	Control T_{t2} system directed to maximum cold fail safe position. Gas generator fuel flow, duct heater fuel flow, duct nozzle, compressor bleeds, and compressor inlet guide vanes scheduled to maximum cold T_{t2} position. Duct heater fuel flow response rate with PLA is constant at approximately SLTO response rate.				
			SLTO: During augmentation, duct nozzle scheduled to full open position. Gas generator and duct heater fuel flow decreases.	Duct nozzle full open. Gas generator fuel flow, duct heater fuel flow, N_1, T_{t7}, and EPR lower than normal.	F_n = 70% F_{nma}	AF and CR	Adjust F_n level on unaffected engines to obtain desired aircraft conditions.
			During nonaugmentation, same as above except duct nozzle scheduled to 4.5 square feet position.	Same as above except duct nozzle at 4.5 square feet position.	F_n = 55% F_{nma} Augmentation may be initiated and F_n increased to value above.	Same as above.	Reinitiate augmentation if additional F_n desired.
			During climb, T_{t2} controlled secondary air bypass duct valves do not close and compressor inlet guide vanes remain in SLTO position.	Position indicator will show valves open above 240°F T_{t2}.	Engine total airflow is higher than normal.	Inlet-engine airflow match will be less than optimum with some loss in performance.	Adjust engine airflow to obtain desired airflow match.
			Cruise: Same as SLTO except compressor inlet guide vanes positioned to SLTO position and T_{t2} controlled secondary air bypass duct valves open.	Same as SLTO	Same as SLTO except during augmentation F_n = 70% F_{nma} During nonaugmentation F_n = 10% F_{nma}	Same as SLTO	Same as LTO. Also, use slower than normal PLA modulation in augmentation range.
			Landing: Same as SLTO	Same as SLTO	Some F_n reduction. If maximum F_n desired, same as SLTO	Same as SLTO	Adjust F_n level with PLA. If maximum F_n desired, [illegible] as SLTO.

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
T_{t2} Servo Piston 2,2,3,10	Positions various cams within the control as a function of T_{t2}.	Seizure	SLTO: T_{t2} servo piston and the T_{t2} positioning of various cams will remain in the position scheduled at time of failure. No affect for conditions existing at time of failure.	Control schedules do not follow normal T_{t2} bias as conditions change.	Not affected	Not affected	None
			During climb, control schedules do not follow normal T_{t2} bias. Gas generator fuel flow higher than normal. Duct heater fuel flow and duct nozzle area less than normal. Compressor inlet guide vanes remain in SLTO position. T_{t2} controlled secondary air bypass duct valves remain open.	Gas generator fuel flow, N_2, T_{t7}, EPR higher than normal. Duct heater fuel flow and duct nozzle area less than normal. Position indicator will show T_{t2} controlled secondary air bypass duct valves open above 240°F T_{t2}.	T_{t7} will eventually exceed limits without crew action. Engine may surge during augmentation even if T_{t7} limits are maintained with remote EPR control.	Eventually, AP CR.	[illegible] necessary to maintain T_{t7} limits, [illegible] [illegible] level on unaffected engines to obtain desired aircraft conditions.
			Cruise: T_{t2} servo piston and T_{t2} positioning of various cams will remain in the position scheduled at time of failure. No affect for conditions existing at time of failure.	None for conditions existing at time of failure.	Not affected	Not affected	None
			During nonaugmented descent and landing at low power settings, compressor inlet guide vanes remain in start-cruise position and T_{t2} controlled secondary air bypass duct valves remain closed below 240°F T_{t2}.	Control schedules do not follow normal T_{t2} bias as conditions change. Position indicator will show T_{t2} controlled secondary air bypass duct valves closed below 240°F T_{t2}.	Power schedules do not follow normal T_{t2} bias as conditions change.	Inlet-engine airflow match will be less than optimum below 240°F T_{t2}.	Modulate PLA to obtain desired descent conditions.
			If maximum F_n desired during landing, schedules remain at high T_{t2} value.	If maximum F_n desired, gas generator fuel flow, duct heater fuel flow, T_{t7}, EPR, N_2 lower than normal.	Maximum F_n not available. F_n ≈ 50% F_{nmax}.	AP and CR	If maximum F_n desired, adjust F_n level on unaffected engines to obtain desired conditions.
			Landing: Not affected	None	Not affected	Not affected	None

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Unitized Control (Continued)

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Required
The following is an addition to Section 3.25.2 Unitized Control Analysis of P&WA Report PDS 2025							
T_{t2} Controlled Secondary Air-flow Bypass Duct Butterfly Valves Pilot Valve 25.2.34.1	Provides positioning fuel pressure signal for two secondary air-flow bypass duct butterfly valve actuators as a function of T_{t2}	Closure	SLTO: Not affected	None	Not affected	Not affected	None
			During climb, the pilot valve will be forced to bypass duct valves closed position by the T_{t2} servo in accordance with normal scheduling.	None	Not affected	Not affected	None
			Cruise: Not affected. On descent the T_{t2} controlled bypass duct valves will remain in the closed position.	None On descent, position indicator will show T_{t2} controlled valves in closed position below 240°F T_{t2}.	Not affected. Maximum augmentation below 240°F T_{t2} at supersonic conditions will shorten life of engine ejector.	Not affected. On descent, inlet-engine airflow match will be less than desired during supersonic conditions below 240°F T_{t2}.	None On descent, adjust engine airflow to obtain desired airflow match. Below 240°F T_{t2} limit augmentation to less than 80% during supersonic conditions.
			Landing: Not affected	None	Not affected	Not affected	None

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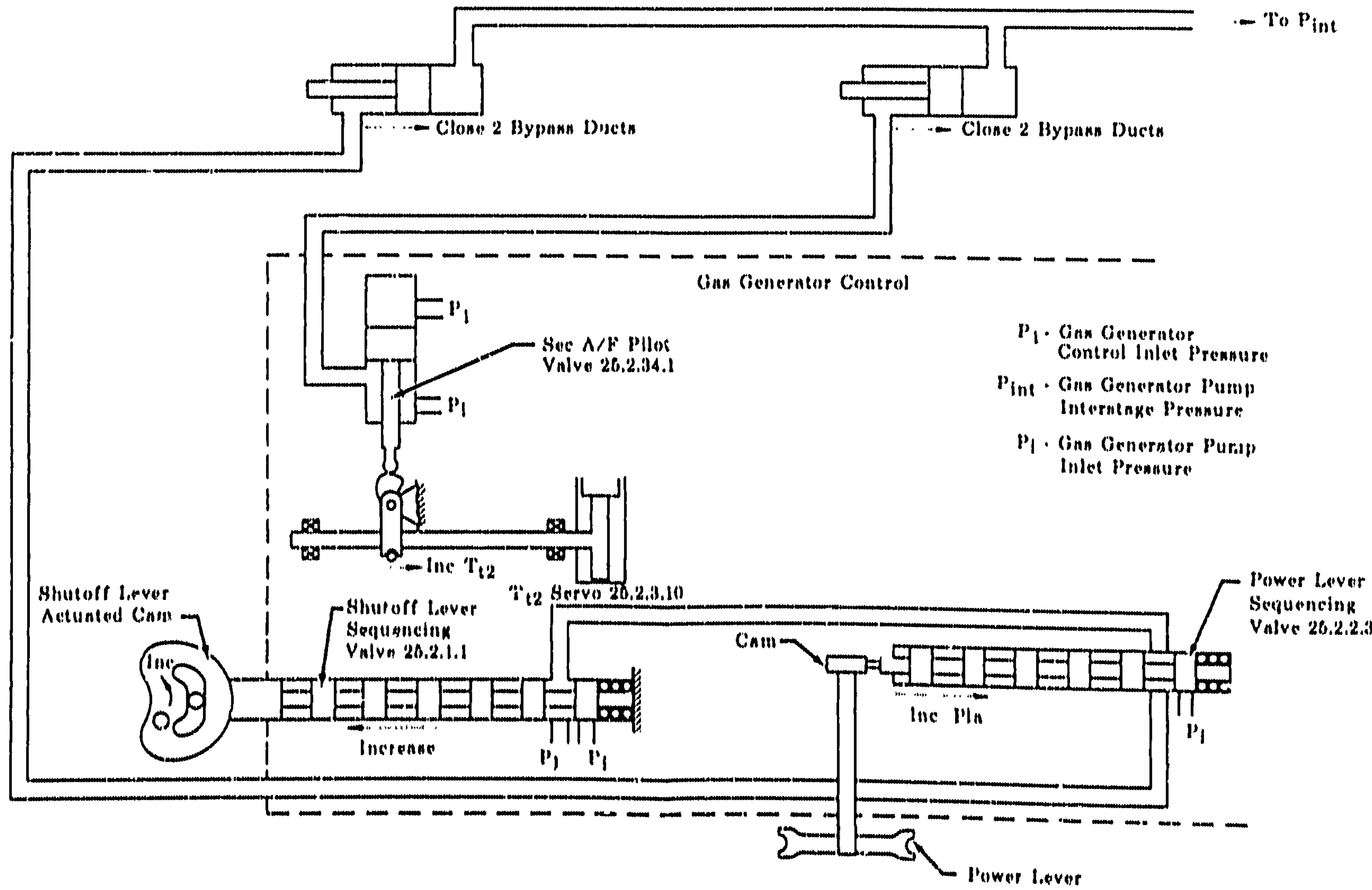
SCHEMATIC OF BOEING SECONDARY AIRFLOW CONTROL SYSTEM



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