ADVANCED SYSTEMS CHECKOUT DESIGN

FIRST QUARTERLY PROGRESS REPORT
FOR PERIOD JUNE 29 THRU SEPTEMBER 29, 1965

CONTRACT NAS8-20240

PREPARED FOR
MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

THE BOEING COMPANY
HUNTSVILLE, ALABAMA

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1.0 INTRODUCTION

On June 29, 1965, The Boeing Company was awarded Contract NAS8-20240 for the "Advanced Systems Checkout Design" study. This study is to determine what checkout functions can and should be performed on-board the Saturn V Instrument Unit and S-IVB stages, how these functions would be mechanized, the impact of these changes on the presently planned Saturn V GSE and schedules, and to develop design guidelines or requirements for incorporating the on-board checkout features.

The concept of Airborne Evaluation Equipment (AEE) is centered on the use of on-board stage equipment for evaluation of stage status. This concept provides a high degree of stage autonomy as regards testing, providing consistent results through all phases of test and reduces the requirements for support equipment.

1.1 SCOPE OF STUDY

The present checkout method for the Saturn vehicle utilizes extensive support equipment to determine vehicle condition, with access through numerous umbilical connections. The equipment being used varies in type and configuration between the various test locations making test data correlation difficult. With the emergence of this vehicle from a developmental status, the test requirements can be more firmly established and the need for acquiring engineering data reduced. With the advances being made in electronics packaging density, size, and power consumption, it is feasible to perform this new scope of testing with a large share of the evaluation equipment located on the vehicle proper. This would also provide relief in correlation of test results between test sites since the test equipment would travel with the vehicle. It would also be available during the mission to perform an in-flight checkout.

This concept places new emphasis on the interface between the vehicle and support equipment. With an on-board checkout system, the bulk of the data reduction and evaluation can occur on the stages under the overall supervisory control of the support complex computer and status and maintenance information sent to the ground by a data link.

The introduction of this concept will drastically reduce the number of umbilical interconnects and quantity of support equipment making it easier and less costly to accommodate varying configurations of vehicles at checkout complexes.

The implementation of the AEE concept may well be accomplished in degrees, that is, the first step being the placement of the function equipment, in a miniaturized form, on the stage and the second step being where the stage subsystem is re-designed to incorporate the function.

1.2 STUDY ORGANIZATION

This study, in accord with the work statement, is divided into two phases. Phase A consists of a ten month effort to develop the AEE concept and Phase B, a three month effort to generate the guidelines for its incorporation into a space vehicle system. Phase A has further been divided into eight tasks for the purpose of identifying specific jobs within the study, and Phase B into two.

Tasks 1, 2, 3, and 4 are basically for the purpose of defining a vehicle configuration against which various test and checkout concepts can be evaluated. This vehicle configuration is determined using Saturn IB Instrument Unit and S-IVB stage documentation furnished by NASA. Tasks 5 and 6 consist of an investigation into methods to accomplish on-board checkout. Tasks 7 and 8 are studies into the impact and implementation of the concept.

Phase B is divided into two tasks. One is a continuation of Phase A, Task 7 and 8, the other, guidelines for incorporating the concept.

2.0 PROGRESS AND ANTICIPATED WORK

It was planned for the first quarter to perform a detailed study of the Saturn IB Instrument Unit and S-IVB stage configuration and operations to lay a foundation for the AEE concept. Tasks 1, 2, and 3 of the ASCD Study Plan were defined to accomplish this effort.

Tasks 1. Wire by Wire Elimination of Umbilicals. This task provides for a detailed examination into the purpose and function of each umbilical connection between the stages and GSE. Progress consists of the following:

A. Each umbilical wire on the Saturn IB Instrument Unit and S-IVB stage has been identified and cataloged.

B. A representative circuit schematic has been drawn for each umbilical contained on the S-IVB stage and 20% of those on the Instrument Unit.

C. To summarize the above investigation, the S-IVB stage umbilicals have been classified as to types of signals. These signal types are:

1. Analog Measurements
2. Analog Commands
3. Bi Level Measurements (discretes)
4. Bi Level Commands (discretes)
5. Power Supply - Including ground power and excitation to various transducers.
6. Shields
7. Connector Mated Interconnects
8. Spare - Including unassigned and reserved for future use.

These are presented in two charts, signal type by connector and signal type by system (Figure 1 and 2).

A data sheet, 1 of 1348, is enclosed (Figure 3) as an example of the type of data collected in this task.

Task 2. Examination of Stage Operational Functions. This task provides for a detailed examination into the purpose and function of each subsystem aboard the stages. Originally it was intended that this task collect those functional, system orientated schematics that identify each subsystem aboard the stages and learn of their operation for consideration of improved on-board test requirements and techniques. However, this type of schematic has not been available, thus necessitating the development of these drawings from many sources, requiring more time than that programmed. Progress to date has consisted of identifying and sketching approximately 40% of the S-IVB stage subsystems, and the collection of limited information on S-IB-IU systems.

Task 3. Assessment of Checkout Philosophy and Procedures. This task provides for the study and definition of the S-IVB/IU stage checkout philosophy, GSE requirements and maintenance concept. The study is broad and encompasses all checkout phases and requirements from post manufacturing thru prelaunch and orbital checkout. This task is considered 90% complete, accomplishments consists of the following:

A. The S-IVB/IU checkout scheme is defined, starting with post manufacturing checkout through pre-launch and orbital checkout.

B. Gross test requirements for all phases of checkout are identified. This only includes a listing of tests that are contemplated, however, this portion of the task is considered incomplete due to the lack of detailed test requirements for each phase of checkout.

C. The current GSE is partly defined, however, little is known about its utilization.

D. The results of this task have been documented.

It was planned for this quarter to have met the objectives of Tasks 1, 2, 3, and 4 as outlined in the ASCD Study Plan. As seen, the results obtained to date have fallen short of this goal. This plan was based on the availability of adequate documentation to allow for early familiarization of the vehicle configuration and operation. Particularly, Tasks 2 and 3 were for this purpose and were designed to collect and catalogue this information for future reference. The data on hand is considered inadequate to provide a complete understanding of system operation. Therefore, it has been necessary to create an additional task (Task 2A) to provide this information.

BREAKDOWN - SIGNAL TYPE BY CONNECTOR

CONNECTOR NUMBER	ANALOG MEASUREMENT	ANALOG COMMAND	BI LEVEL MEASUREMENT	BI LEVEL COMMAND	SPARE	SHIELD	POWER SUPPLY	CONNECTOR MATED
411W1J1	8		39		9	4		
411W2J1	6	2	2	37	4	1	8	
411W17J1	6			4	14		5	
411W17J2	7				15		7	
411W20J1				21	34	1	2	2
411W203J1	5				1			
404W1J1				48	10			2
404W2J1	8		43		3	4		2
404W3J1		10	2	46				2
404W4J1	8	2	35		4	5	4	2
404W15J1	9		1	6			13	
404W15J2	6		4	5	9		5	
	63	14	126	167	103	15	44	10

FIGURE 1

NAS 8-20240 (3)

BREAKDOWN - TYPE BY SYSTEM SIGNAL

SIGNAL TYPE	S-IVB STAGE SYSTEMS BY SEQUENCE NUMBERS																		
	C1	C2	C3	C4	C5	C6	C7	C8	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	TOTAL
1. ANALOG MEAS.			6	2			2		2		28	4		6		3	2	8	63
CLASS A 0-28 V			4						2		20			6		2	2		36
CLASS B 0-5 V			2	2															4
CLASS C OTHER							2				8	4				1		8	23
2. ANALOG COMMAND							2		10					2					14
CLASS A 0-28 V																			0
CLASS B 0-5 V																			0
CLASS C OTHER							2		10					2					14
3. BI LEVEL MEAS.	9	12	7	8	3		16		1	5	13	2	8	2	13	9	7	11	126
4. BI LEVEL COMM.	1	10	8	5	3		23		1	1	54	3	12	2	23	5	2	14	167
5. POWER SUPPLY			2	2							30			4	2	2	2		44
6. SHIELD			4	2						1				1	1	1	1	4	15
7. CONN. MATED											10								10
8. SPARE																		103	103
TOTAL																			542

FIGURE 2A

Sequence numbers are assigned to each system by the Douglas Aircraft Company. These are used in the following chart.

C1	Engine Start System
C2	Engine Cutoff System
C3	Fuel Tank Pressurization System
C4	LOX Tank Pressurization System
C5	Control Helium System
C6	APS Leak Detection System (S5)
C7	Attitude Control System
C8	Propulsion Leak Detection System
C10	Flight Control System
C11	Auxiliary Hydraulic System
C12	Power Distribution System
C13	EBW System
C14	Propellant Utilization Loading System
C15	Propellant Utilization Flight System
C16	Data Acquisition Control System
C17	Range Safety System No. 1
C18	Range Safety System No. 2
C19	Engine Checkout System

FIGURE 2B

UMBILICAL: S-IVB Aft Umbilical

CONNECTOR NUMBER: 404W2J1 Pin 18

TITLE: Measurement Fuel Chilldown Shutoff Valve Open

FROM: S-IVB to GSE

WIRE FUNCTION: Measurement

RECOMMENDATION: On-Board Measurement Feasible

1. Check Utilization of T/M Points

2. Check Utilization of Valve Mounted Sensor

PROCEDURE:

1. Delete Bus 4D119
   Delete S1 Contacts F, E, and D.
   Utilize T/M Point for On-Board Measurement
   Increase Capacity at Bus 4D11

2.

EQUIPMENT &/OR CHANGES REQUIRED:

On-Board Evaluator Required

EFFECT ON TEST PHILOSOPHY OR PROCEDURES:

None

EFFECT ON GSE:

Deletion

FIGURE 3A

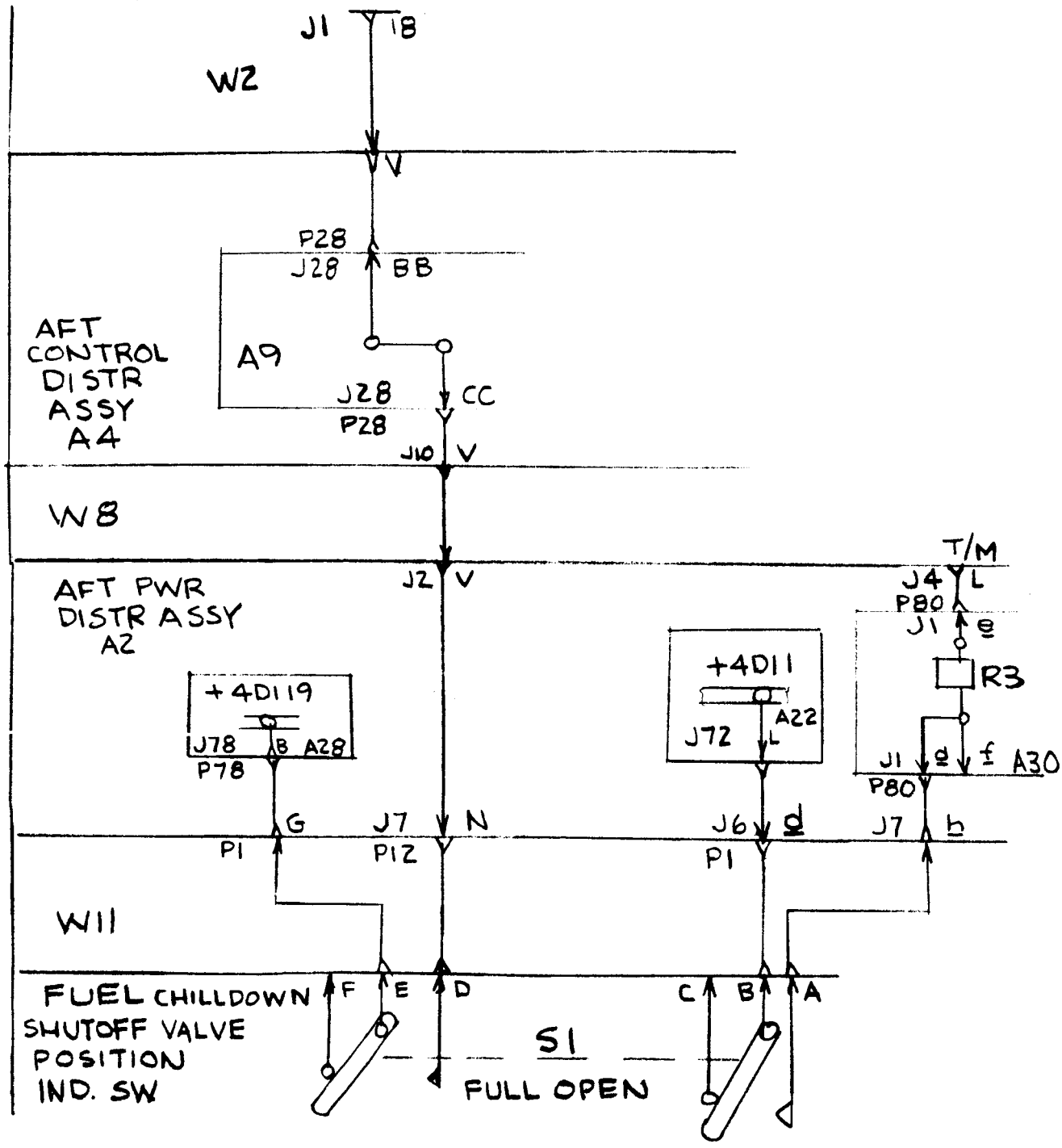

J1
18
W2
P28
J28
BB
AFT
CONTROL
DISTR
ASSY
A4
A9
J28
P28
CC
J10
V
W8
J2
V
AFT PWR
DISTR ASSY
A2
T/M
J4
L
P80
J1
e
R3
+4D119
J78
B
A28
P78
+4D11
A22
J72
L
J1
g
f
A30
P80
G
P1
J7
N
P12
J6
d
P1
J7
h
W11
FUEL CHILLDOWN
SHUTOFF VALVE
POSITION
IND. SW
F
E
D
C
B
A
S1
FULL OPEN

FIGURE 3B

Task 2A is designed to collect information from many sources and develop system schematics to aid in the identification of present test techniques and allow for the establishment of new or altered test techniques. As an example, the propellant management system description and schematics developed for this purpose are enclosed. This schematic was developed from Advanced Functional Schematics furnished by NASA and from a Boeing company training manual.

This task, utilizing present information on the S-IVB stage is scheduled to be completed by November 1. Similar schematics will be required for the instrument unit. However, the documentation is not available for this purpose, and when received may be of a type readily used, not requiring a continuation of Task 2A.

Task 1 completion is dependent upon receipt of IU system documents and S-IVB/IU test requirements. This task cannot be completed or continued until further documentation is received. During this interim, the DDAS and PCM telemetry system will be studied for utilization or adaption and modification into on-board test systems. This is planned for completion by October 15.

Further work on Task 3 will be suspended until a later date when information on a more selected basis will be required and more information made available.

Task 4 is expected to begin October 15 with respect to on-board test techniques as system information becomes available through Task 2A. System concepts, however, cannot be finalized until actual detailed test requirements are known.

3.0 SCHEDULING AND MANNING

A chart containing the information is shown in Figure 4 and reflects the following changes:

A. Identification of stage checkout functions extended one month.

B. Mechanization of AEE delayed until October 15.

C. Manning level at eight men extended one month.

4.0 PROBLEMS

Test and checkout concepts are totally dependent on the configuration and use of the system to be tested. The ASCD Study Plan is organized in this manner and approximately three months effort is provided for this purpose. It was assumed during this planning that not only quantities of data would be quickly provided by NASA, but this data would be of a type that can readily be used to gain an understanding of system operation. This has not been the case. The data furnished is incomplete and has arrived in parts.

For the study of the S-IVB stage, the data furnished has basically consisted of Advanced Functional Schematics and Systems Design Test

and Checkout Requirements. The schematics are sufficient to trace umbilical lines to their source, however, due to their lack of system orientation, a system analysis is difficult to accomplish. Further, in configuring a test controller, test requirements must be known. These requirements must consist of sequencing, tolerances, magnitudes, prerequisites, ect., for more than that covered in the document provided. Also it was assumed that a document would be provided that describes the operation of the vehicle, for example, how the propellant utilization system works in detail, the countdown sequencing, range safety, fueling sequences, emergency detection system, ect.

For the study of the Instrument Unit, the information provided has consisted of the Astrionics Systems Handbook and an interconnect wiring schematic, far less useable data than received for the S-IVB stage. For this study, the same data is required as described in the preceeding paragraph.

Many attempts have been made to secure this data from internal sources with limited success. In any event this is costly, time consuming, and the data obtained has been of little use.

Further, the above information, when provided will allow the formulation of on-board test concepts, for a cost and effectiveness analysis and an integration plan other information must be forthcoming.

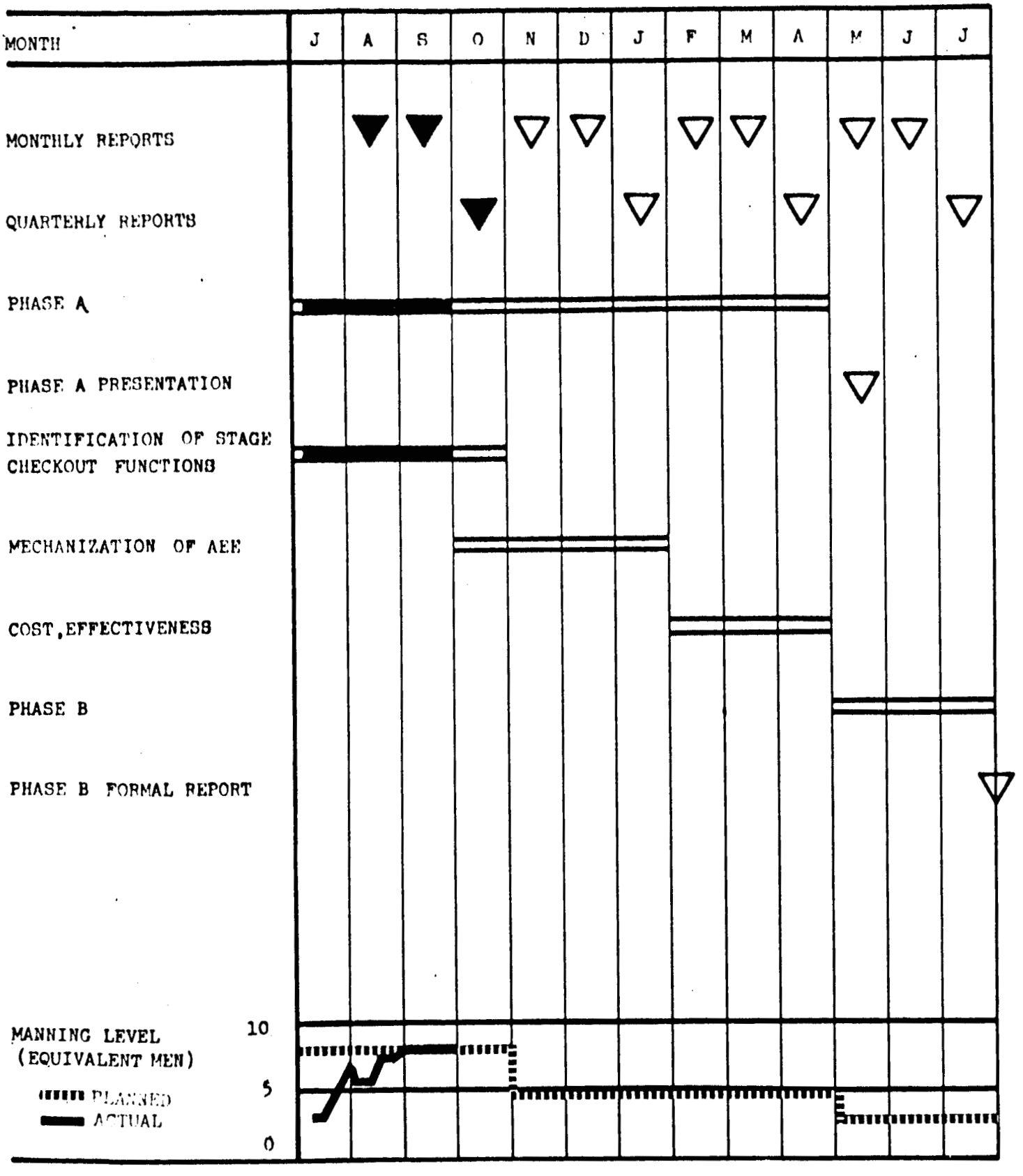


FIGURE 4

PROGRAM SCHEDULE AND MANPOWER EXPEDITURE

PROPELLANT MANAGEMENT SYSTEM

I. GENERAL DESCRIPTION

The S-IVB propellant management system provides control, monitoring and checkout for propellant loading mass indication and propellant utilization. In S-V S-IVB system propellant depletion capability is added.

Major Components

Fuel Mass Probe - capacitive type
LOX Mass Probe - capacitive type
P.U. Electronics Assembly - provides control signals
Inverter Converter - converts 28 VDC from Forward No. 2 Battery into AC and DC for P.U. Electronics Assembly
Fast - fill cutoff sensors (2)
Emergency Over-fill Cutoff Sensors (2)
Engine Propellant Utilization Valve
LH_2 Tank Engine Cutoff Sensors (3)
LOX Tank Engine Cutoff Sensors (3)

II. OPERATION

Propellant Loading System

The capacitance of the continuous probes vary proportionally to the mass of propellant in the tanks. The P.U. Electronics Assembly converts the capacitance of the probes to electrical signals during loading and utilization during flight. The fast-fill and over-fill cutoff sensors prevent over-fill in the event the P.U. Electronics Assembly signal fails.

The loading operation begins with LOX chilldown. Chilldown flow continues to 5% of full load at which time fast-fill starts and continues until 95% level loading. Then continues at the slow-fill rate to 100%. The GSE replenish valve maintains the 100% level by establishing fill rates equal to boil-off rates.

Propellant Utilization Flight System

Measures and controls the LOX/LH_2 flow rate and generates error signal representing deviation from the desired LOX/LH_2 mixture ratio required. The signal is utilized in the servo system which controls the mixture ratio of the engine propellant utilization valve by by-passing portion of LOX from LOX pump back to engine pump.

ENCLOSURE

PROPELLANT MANAGEMENT SYSTEM

II. OPERATION (Continued)

Propellant Depletion System

Initiates a signal to shut down the engines at propellant depletion to minimize propellant residuals. The signal is generated when two out of three sensors from the same tank indicate depletion.

III. SYSTEM BLOCK DIAGRAM

Enclosed (1 page)

IV. SYSTEM SCHEMATIC DIAGRAM

Enclosed (4 pages)

V. PRESENT TEST REQUIREMENT

Identify test points and/or umbilicals for

1. Manufacturing
2. Pre-Launch
3. Orbital

Unknown

VI. TREATMENT OF EMERGENCY, HOLD, CUTOFF, ETC.

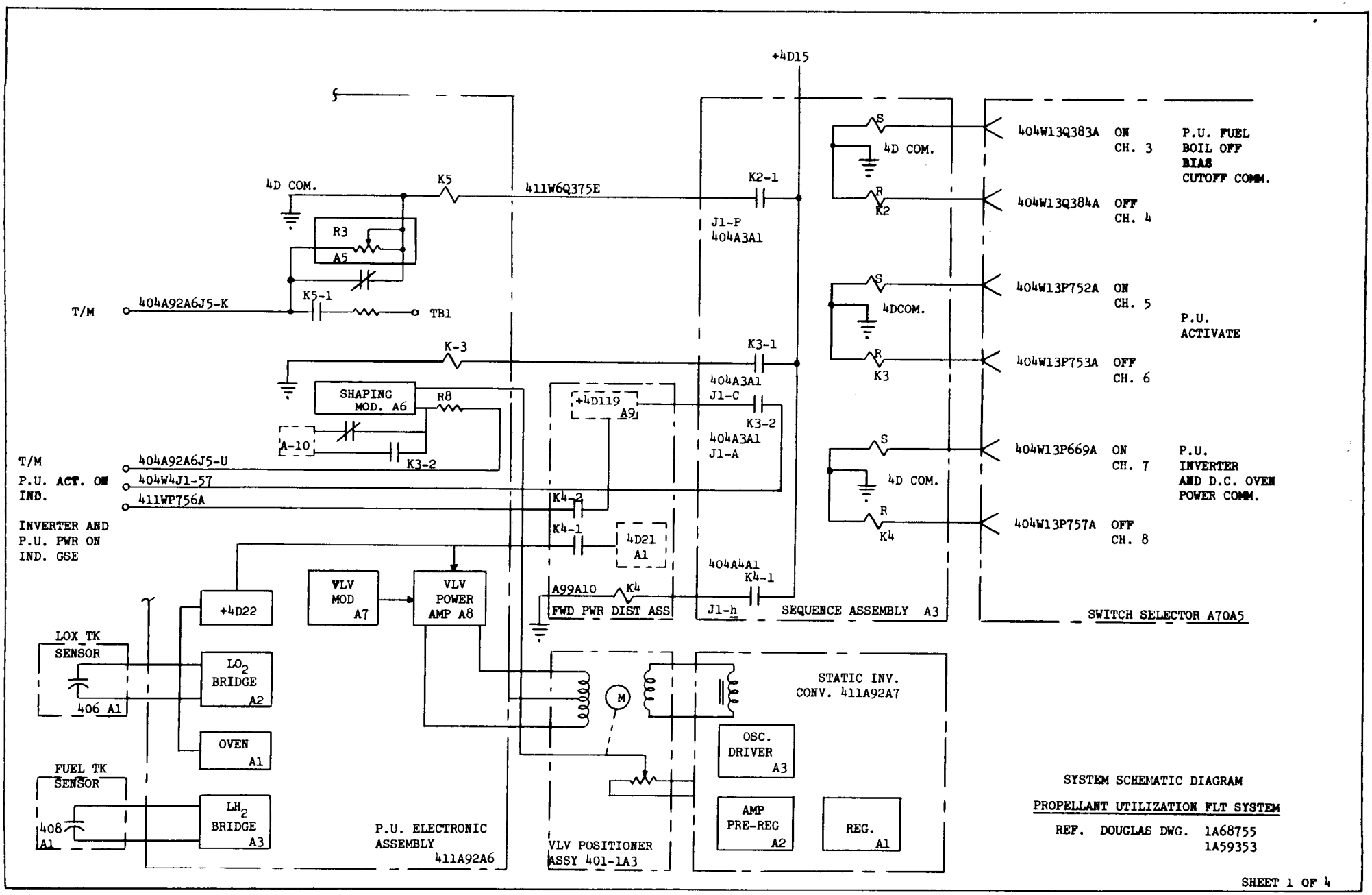
Unknown

VII. APPLICATION OF AEE TECHNIQUE

Unknown

VIII. IMPACT DUE TO APPLICATION OF AEE TECHNIQUE

Unknown

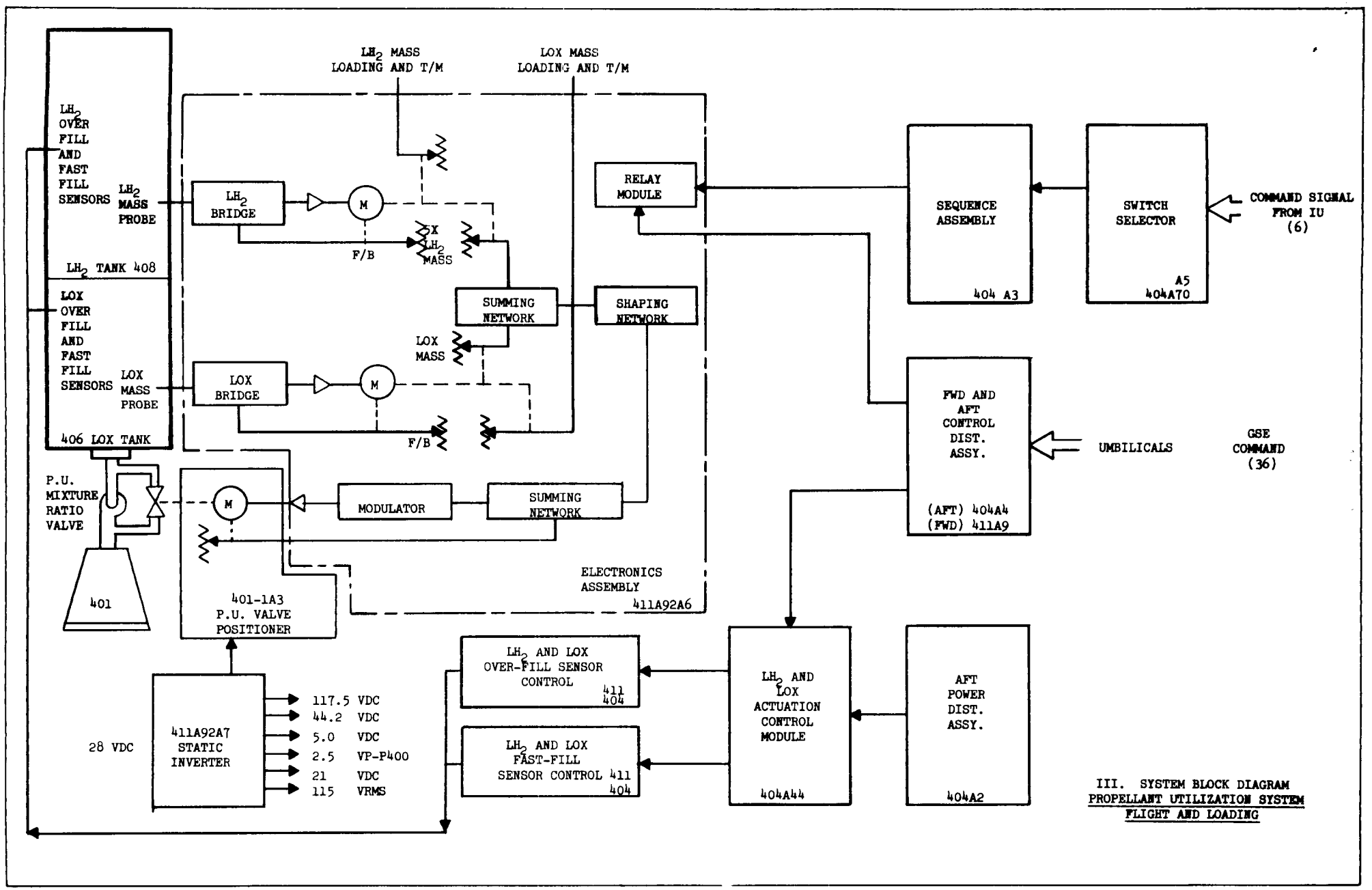


SYSTEM SCHEMATIC DIAGRAM

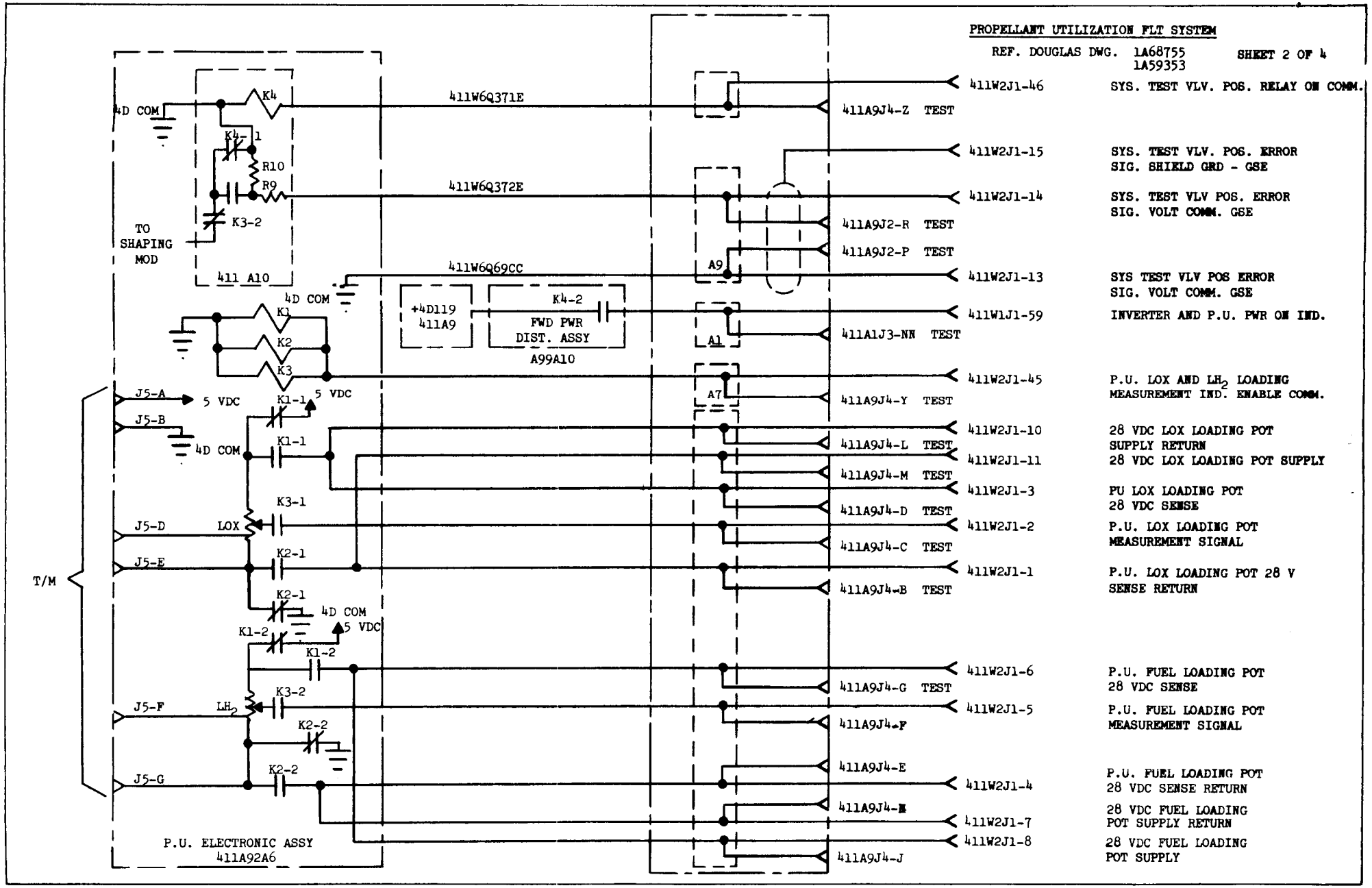
PROPELLANT UTILIZATION FLT SYSTEM

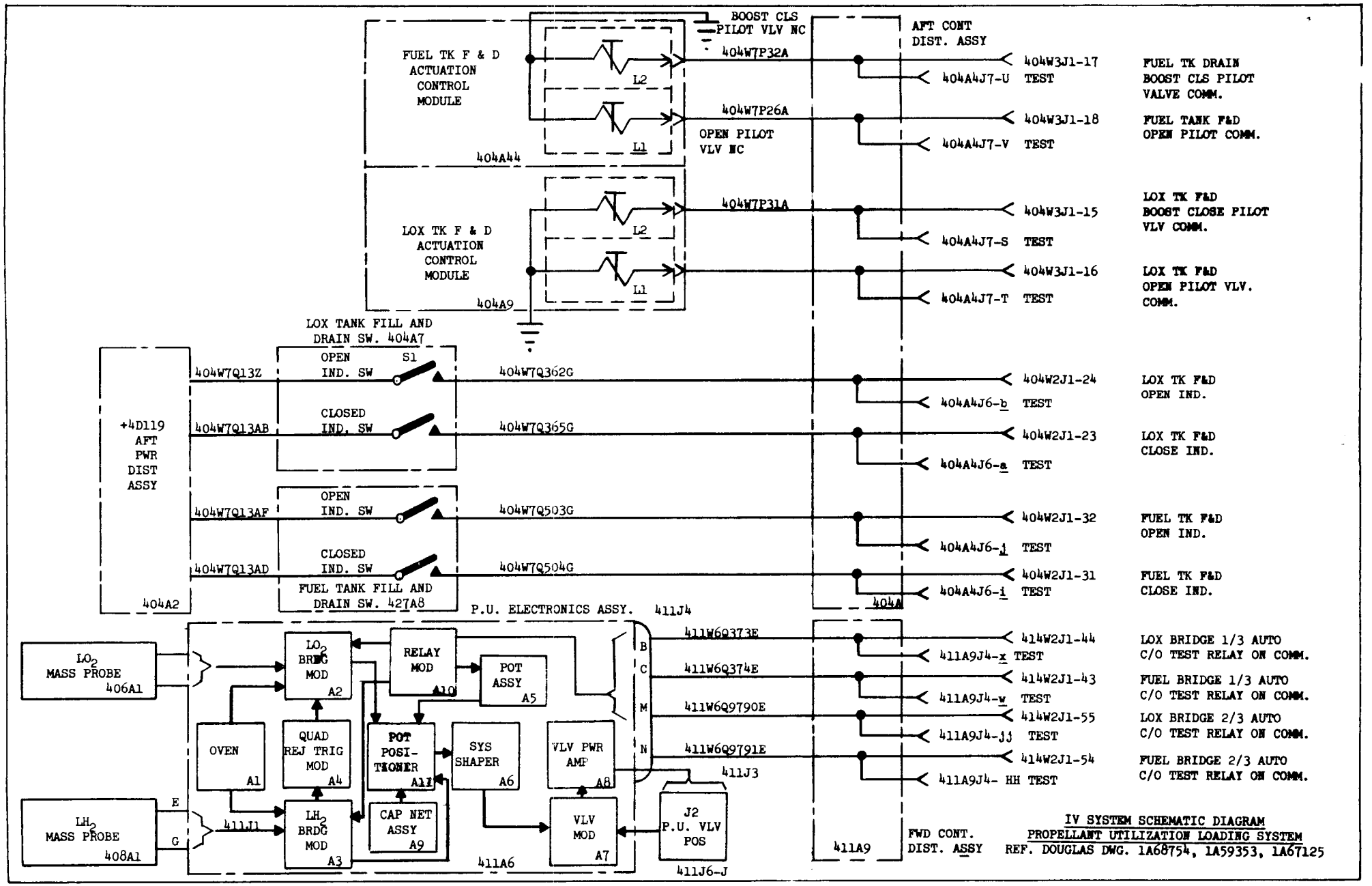
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1A59353

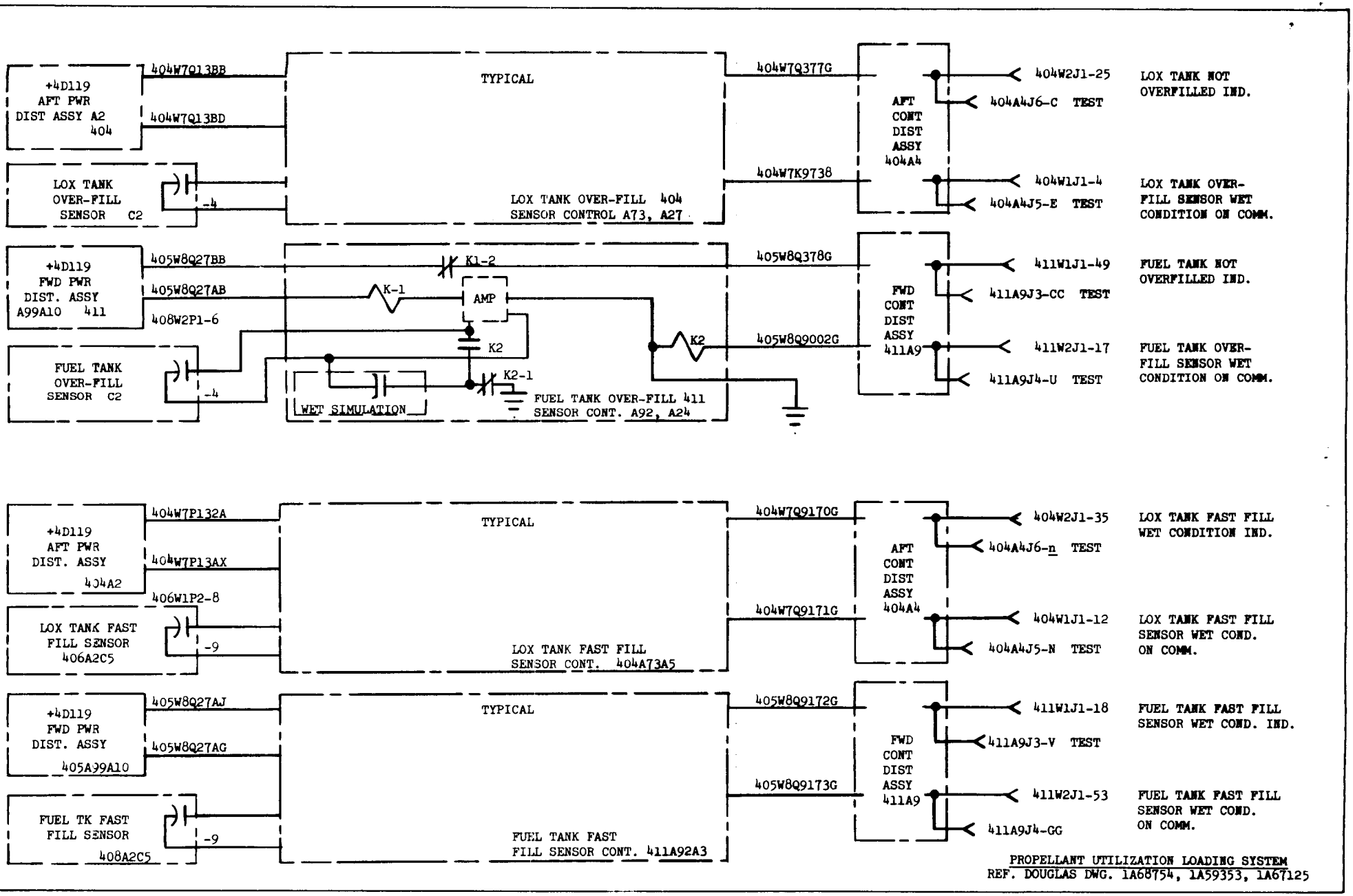
SHEET 1 OF 4



III. SYSTEM BLOCK DIAGRAM
PROPELLANT UTILIZATION SYSTEM
FLIGHT AND LOADING


PROPELLANT UTILIZATION FLT SYSTEM
REF. DOUGLAS DWG. 1A68755 1A59353
SHEET 2 OF 4
4D COM
K4
K4-1
R10
R9
K3-2
TO SHAPING MOD
411 A10
411W6Q371E
411W6Q372E
411W6Q69CC
+4D119 411A9
K4-2
FWD PWR DIST. ASSY
A99A10
K1
K2
K3
J5-A
5 VDC
J5-B
K1-1
K3-1
J5-D
LOX
J5-E
K2-1
T/M
K1-2
J5-F
LH2
K2-2
J5-G
P.U. ELECTRONIC ASSY
411A92A6
A9
A1
A7
411W2J1-46
411A9J4-Z TEST
SYS. TEST VLV. POS. RELAY ON COMM.
411W2J1-15
SYS. TEST VLV. POS. ERROR
SIG. SHIELD GRD - GSE
411W2J1-14
411A9J2-R TEST
411A9J2-P TEST
SYS. TEST VLV POS. ERROR
SIG. VOLT COMM. GSE
411W2J1-13
SYS TEST VLV POS ERROR
SIG. VOLT COMM. GSE
411W1J1-59
411A1J3-NN TEST
INVERTER AND P.U. PWR ON IND.
411W2J1-45
411A9J4-Y TEST
P.U. LOX AND LH2 LOADING
MEASUREMENT IND. ENABLE COMM.
411W2J1-10
411A9J4-L TEST
28 VDC LOX LOADING POT
SUPPLY RETURN
411W2J1-11
411A9J4-M TEST
28 VDC LOX LOADING POT SUPPLY
411W2J1-3
411A9J4-D TEST
PU LOX LOADING POT
28 VDC SENSE
411W2J1-2
411A9J4-C TEST
P.U. LOX LOADING POT
MEASUREMENT SIGNAL
411W2J1-1
411A9J4-B TEST
P.U. LOX LOADING POT 28 V
SENSE RETURN
411W2J1-6
411A9J4-G TEST
P.U. FUEL LOADING POT
28 VDC SENSE
411W2J1-5
411A9J4-F
P.U. FUEL LOADING POT
MEASUREMENT SIGNAL
411A9J4-E
411W2J1-4
P.U. FUEL LOADING POT
28 VDC SENSE RETURN
411A9J4-H
411W2J1-7
28 VDC FUEL LOADING
POT SUPPLY RETURN
411W2J1-8
411A9J4-J
28 VDC FUEL LOADING
POT SUPPLY


BOOST CLS PILOT VLV NC
AFT CONT DIST. ASSY
FUEL TK F & D ACTUATION CONTROL MODULE
404W7P32A
404W3J1-17
404A4J7-U TEST
FUEL TK DRAIN BOOST CLS PILOT VALVE COMM.
L2
404W7P26A
404W3J1-18
404A4J7-V TEST
FUEL TANK F&D OPEN PILOT COMM.
OPEN PILOT VLV NC
L1
404A44
LOX TK F & D ACTUATION CONTROL MODULE
404W7P31A
404W3J1-15
404A4J7-S TEST
LOX TK F&D BOOST CLOSE PILOT VLV COMM.
404W3J1-16
404A4J7-T TEST
LOX TK F&D OPEN PILOT VLV. COMM.
404A9
LOX TANK FILL AND DRAIN SW. 404A7
OPEN IND. SW
S1
404W7Q13Z
404W7Q362G
404W2J1-24
404A4J6-b TEST
LOX TK F&D OPEN IND.
+4D119 AFT PWR DIST ASSY
CLOSED IND. SW
404W7Q13AB
404W7Q365G
404W2J1-23
404A4J6-a TEST
LOX TK F&D CLOSE IND.
OPEN IND. SW
404W7Q13AF
404W7Q503G
404W2J1-32
404A4J6-j TEST
FUEL TK F&D OPEN IND.
CLOSED IND. SW
404W7Q13AD
404W7Q504G
404W2J1-31
404A4J6-i TEST
FUEL TK F&D CLOSE IND.
FUEL TANK FILL AND DRAIN SW. 427A8
404A2
404A
P.U. ELECTRONICS ASSY. 411J4
LO2 MASS PROBE 406A1
LO2 BRDG MOD A2
RELAY MOD A10
POT ASSY A5
411W6Q373E
414W2J1-44
411A9J4-x TEST
LOX BRIDGE 1/3 AUTO C/O TEST RELAY ON COMM.
411W6Q374E
414W2J1-43
411A9J4-w TEST
FUEL BRIDGE 1/3 AUTO C/O TEST RELAY ON COMM.
411W6Q790E
414W2J1-55
411A9J4-jj TEST
LOX BRIDGE 2/3 AUTO C/O TEST RELAY ON COMM.
411W6Q791E
414W2J1-54
411A9J4- HH TEST
FUEL BRIDGE 2/3 AUTO C/O TEST RELAY ON COMM.
OVEN A1
QUAD REJ TRIG MOD A4
POT POSI-TIONER A11
SYS SHAPER A6
VLV PWR AMP A8
411J3
LH2 MASS PROBE 408A1
411J1
LH2 BRDG MOD A3
CAP NET ASSY A9
VLV MOD A7
J2 P.U. VLV POS
411A6
411J6-J
411A9
FWD CONT. DIST. ASSY
IV SYSTEM SCHEMATIC DIAGRAM
PROPELLANT UTILIZATION LOADING SYSTEM
REF. DOUGLAS DWG. 1A68754, 1A59353, 1A67125


+4D119
AFT PWR
DIST ASSY A2
404
404W7Q13BB
404W7Q13BD
LOX TANK
OVER-FILL
SENSOR C2
-4
TYPICAL
LOX TANK OVER-FILL 404
SENSOR CONTROL A73, A27
404W7Q377G
404W7K9738
AFT
CONT
DIST
ASSY
404A4
404W2J1-25
404A4J6-C TEST
404W1J1-4
404A4J5-E TEST
LOX TANK NOT
OVERFILLED IND.
LOX TANK OVER-
FILL SENSOR WET
CONDITION ON COMM.
+4D119
FWD PWR
DIST. ASSY
A99A10 411
405W8Q27BB
405W8Q27AB
408W2P1-6
FUEL TANK
OVER-FILL
SENSOR C2
-4
K1-2
K-1
AMP
K2
K2-1
WET SIMULATION
FUEL TANK OVER-FILL 411
SENSOR CONT. A92, A24
405W8Q378G
405W8Q9002G
FWD
CONT
DIST
ASSY
411A9
411W1J1-49
411A9J3-CC TEST
411W2J1-17
411A9J4-U TEST
FUEL TANK
OVER-FILL
SENSOR WET
CONDITION ON COMM.
+4D119
AFT PWR
DIST. ASSY
404A2
404W7P132A
404W7P13AX
406W1P2-8
LOX TANK FAST
FILL SENSOR
406A2C5
-9
TYPICAL
LOX TANK FAST FILL
SENSOR CONT. 404A73A5
404W7Q9170G
404W7Q9171G
AFT
CONT
DIST
ASSY
404A4
404W2J1-35
404A4J6-n TEST
404W1J1-12
404A4J5-N TEST
LOX TANK FAST FILL
WET CONDITION IND.
LOX TANK FAST FILL
SENSOR WET COND.
ON COMM.
+4D119
FWD PWR
DIST. ASSY
405A99A10
405W8Q27AJ
405W8Q27AG
FUEL TK FAST
FILL SENSOR
408A2C5
-9
TYPICAL
FUEL TANK FAST
FILL SENSOR CONT. 411A92A3
405W8Q9172G
405W8Q9173G
FWD
CONT
DIST
ASSY
411A9
411W1J1-18
411A9J3-V TEST
411W2J1-53
411A9J4-GG
FUEL TANK FAST FILL
SENSOR WET COND. IND.
FUEL TANK FAST FILL
SENSOR WET COND.
ON COMM.
PROPELLANT UTILIZATION LOADING SYSTEM
REF. DOUGLAS DWG. 1A68754, 1A59353, 1A67125