NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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REVISION 1 TO THE CONSUMABLES ANALYSIS FOR THE APOLLO 10 (MISSION F) SPACECRAFT OPERATIONAL TRAJECTORY

Guidance and Performance Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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PROJECT APOLLO

REVISION 1 TO THE CONSUMABLES ANALYSIS FOR THE APOLLO 10 (MISSION F) SPACECRAFT OPERATIONAL TRAJECTORY

By Martin L. Alexander, Sam A. Kamen, Arnold J. Loyd,
Samuel O. Mayfield, Dwight G. Peterson,
Walter Scott, Jr., and Richard M. Swalin
Guidance and Performance Branch

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MISSION PLANNING AND ANALYSIS DIVISION
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FOREWORD

The following table summarizes the consumables requirements for the Apollo 10 mission, May 18 launch. Percentages refer to nominal usage only and do not include dispersions and contingencies.

Consumable	Percentage of available consumable used for mission planning
CM RCS	15
SM RCS	73
SPS	92
LM RCS	59
DPS	6
APS through rendezvous[a]	8
CSM O_2	62
CSM H_2	73
LM descent battery	27
LM ascent battery	71
LM ascent H_2O	59
LM descent H_2O	21
LM ascent O_2	31
LM descent O_2	8

[a]From rendezvous through the depletion burn, the remaining 92% propellant is used.

The results were obtained from detailed consumables analyses performed on the Apollo 10 systems and include Apollo 8 and 9 postflight data as well as Apollo 10 simulation data. A time history of total consumables weight loss is also presented. Consumables for all systems anlayzed have adequate margins to complete the nominal mission.

The principal sources of data were the data books (refs. 1, 2, and 3). The analyses were based on the Apollo 10 draft final flight plan (ref. 4). The operational procedures described in this study are not intended to define mission rules or crew procedures but are merely an attempt to establish an estimate of the consumables requirements.

Support was obtained from TRW Systems Group, from North American Rockwell, from Grumman Aircraft Engineering Corporation, from the Apollo Spacecraft Program Office, and from the Instrumentation and Electronics System Division.

ABBREVIATIONS

AGS	abort guidance system
APS	ascent propulsion system
CDH	constant differential height
CM	command module
COAS	crew optical alinement sight
CSI	concentric sequence initiation
CSM	command and service modules
DB	deadband
DAP	digital autopilot
DOI	descent orbit insertion
DPS	descent propulsion system
ECS	environmental control system
EECOM	electrical, environmental, and communications
EPS	electrical power system
F.T.P.	full throttle position
H_2	hydrogen
IMU	inertial measurement unit
I_{fc}	fuel cell current
I_{sp}	specific impulse
LM	lunar module
LOI	lunar orbit insertion
LOS	line of sight

LPO	lunar parking orbit
MCC	midcourse correction
MI	minimum impulse
MPAD	Mission Planning and Analysis Division
MSFN	Manned Spaceflight Network
NR	North American Rockwell
ORDEAL	orbital rate display, earth and lunar
O_2	oxygen
PGNCS	primary guidance and navigation control subsystem
PTC	passive thermal control
RCS	reaction control system
REV	revolution
RR	rendezvous radar
SCS	stabilization and control subsystem
SEP	separation
SLA	spacecraft/LM adapter
SM	service module
SPS	service propulsion system
SPS-n	number of the SPS burn; n = 1, ..., 8
T, D, and E	transposition, docking, and extraction
TEC	transearth coast
TEI	transearth injection
TLC	translunar coast
TLMC	translunar midcourse correction

TPI	terminal phase initiation (of rendezvous)
TPF	terminal phase finalization (of rendezvous)
t	time
WT	weight

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1.0 THE CM RCS ANALYSIS

The CM RCS propellant data were taken from reference 1. Usage data were taken from reference 5. The CM RCS propellant summary is presented in table 1-I.

TABLE 1-I.- CM RCS PROPELLANT SUMMARY

Item	RCS propellant used, lb	RCS propellant remaining, lb
Loaded	--	245.0
Trapped	36.4	208.6
Available for mission planning	--	208.6
Nominal usage	30.8	177.8
Margin	--	177.8

2.0 THE SM RCS ANALYSIS

TABLE 2-I.- GROUND RULES AND ASSUMPTIONS FOR THE SM RCS ANALYSIS

The following ground rules were used to calculate the SM RCS budget.
1. The first and third MCC's (translunar) are executed as SPS burns with the third MCC trimmed with the RCS.
2. Passive thermal control is assumed to be in the PGNCS wide deadband control mode and to require 1 lb/hr, compared with 1.1 to 1.7 lb/hr requirement on Apollo 8 in the SCS control mode.
3. The sixth MCC (transearth) is executed as an RCS burn of 5 fps.

TABLE 2-II.- SM RCS PROPELLANT LOADING AND USAGE SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Expected loading[a]		1342.4
Initial outage caused by loading mixture ratio[a]	15.6	
Total trapped[a]	26.4	
Gaging inaccuracy[a]	80.4	
Deliverable[a]		1220.0
Nominal Usage		
Lift-off through SPS burn to evade S-IVB	114.0	1106.0
Remainder of translunar period	199.5	906.5
LOI-1 to undocking	116.3	790.2
Undocking through two REVS beyond docking	224.2	566.0
Remainder of lunar stay to TEI	66.3	499.7
TEI through CM/SM separation	141.4	358.3
Outage caused by mission duty cycle mixture ratio shift	36.8	321.5
Nominal remaining		321.5

[a]Data provided by Auxiliary Propulsion and Pyrotechnics Branch of Propulsion and Power Division.

TABLE 2-III.- SM RCS PROPELLANT BUDGET

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
.0	MISSION F	63529.	.0	1220.0	100.
.0	SM-RCS CHECKOUT NON PROPULSIVE	63529.	.0	1220.0	100.
3.1	TRANSPOSITION AND DOCKING +X .8FPS, NULL TO 0.3 FPS	63517.	12.2	1207.8	99.
3.1	PITCH TO ACQUIRE SIVB PITCH 180 DEG 1.5DEG/SEC	63514.	2.3	1205.5	99.
3.1	ROLL CSM AT 0.5 DEG/SEC	63514.	.4	1205.1	99.
3.1	NULL DELTA V	63504.	9.5	1195.6	98.
3.1	PHOTOGRAPHY AND SYSTEMS FAMILIARIZATIONINCREASED PER APOLLO 9 RESULTS	63455.	49.3	1146.3	94.
3.2	INDEX AND DOCK LANGLEY STUDY	63429.	26.0	1120.3	92.
4.1	LM EJECTION PLUS RCS BURN 4 JETS, 5 SEC	94267.	7.9	1112.4	91.
4.5	SPS BURN TO EVADE SIVB 3 AXIS ORIENT PGNCS	94263.	4.1	1108.3	91.
4.5	ATTITUDE HOLD	94263.	.4	1107.9	91.
4.5	SPS BURN BUILD UP	94260.	.0	1107.9	91.
4.5	STEADY STATE BURN 11	94225.	.1	1107.8	91.
4.5	TAILOFF	94184.	.8	1107.1	91.
4.5	DAMP SHUTDOWN TRANSIENT	94182.	1.1	1106.0	91.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
4.7	ORIENT TO MONITOR SLINGSHOT 0.2 DEG/SEC PGNCS	94178.	4.1	1101.8	90.
5.0	P52 IMU ALIGN	94175.	2.8	1099.0	90.
5.5	ORIENT FOR NAV SIGHTINGS SET 1	94171.	4.1	1094.9	90.
5.6	ORIENT FOR NAV SIGHTINGS SET 2	94167.	4.1	1090.8	89.
5.7	ORIENT FOR NAV SIGHTINGS SET 3	94163.	4.1	1086.6	89.
5.8	ORIENT FOR NAV SIGHTINGS SET 4	94159.	4.1	1082.5	89.
5.9	ORIENT FOR NAV SIGHTINGS SET 5	94155.	4.1	1078.3	88.
5.9	ALLOW FOR MIN DB HOLD DURING SIGHTINGS	94153.	1.8	1076.5	88.
5.9	SPACECRAFT IN RANDOM DRIFT	94153.	.0	1076.5	88.
9.2	P52 IMU ALIGN	94150.	2.8	1073.7	88.
9.2	MCC1, NO ULLAGE, NO TRIM	94146.	4.1	1069.6	88.
9.2	ATTITUDE HOLD 5 DEG DB	94146.	.4	1069.2	88.
9.2	SPS BURN BUILD UP	94143.	.0	1069.2	88.
9.2	STEADY STATE BURN 11	94108.	.1	1069.1	88.
9.2	TAILOFF	94067.	.8	1068.3	88.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
9.2	DAMP SHUT,DOWN TRANSIENT	94065.	1.1	1067.2	87.
12.0	P52 IMU ALIGN	94063.	2.8	1064.4	87.
12.0	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	94059.	4.0	1060.4	87.
12.0	ESTABLISH ROLL	94058.	.4	1060.0	87.
18.0	12.7 HRS OF PITCH AND YAW CONTROL	94046.	12.7	1047.3	86.
24.7	P52 IMU ALIGN	94043.	2.8	1044.5	86.
25.3	ORIENT FOR NAV SIGHTINGS SET 1	94039.	4.1	1040.4	85.
25.4	ORIENT FOR NAV SIGHTINGS SET 2	94034.	4.1	1036.3	85.
25.5	ORIENT FOR NAV SIGHTINGS SET 3	94030.	4.1	1032.1	85.
25.6	ORIENT FOR NAV SIGHTINGS SET 4	94026.	4.1	1028.0	84.
25.7	ORIENT FOR NAV SIGHTINGS SET 5	94022.	4.1	1023.9	84.
25.7	ALLOW FOR MIN DB DURING SIGHTINGS	94019.	3.4	1020.4	84.
26.4	SXT STAR CHECK	94016.	2.3	1018.1	83.
26.5	MIDCOURSE CORRECTION NO 2 MNVR TO BURN ATT	94012.	4.1	1014.0	83.
26.5	ATT HOLD .5 DEG DB PGNCS	94012.	.3	1013.8	83.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
26.5	DELTA VEL = NOMINALLY ZERO	94012.	.0	1013.8	83.
27.0	ORIENT FOR S-BAND REFLECTIVITY TEST	94008.	4.1	1009.6	83.
27.1	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	94004.	4.1	1005.6	82.
27.1	ESTABLISH ROLL	94003.	.4	1005.2	82.
32.0	PITCH AND YAW CONTROL	93995.	8.7	996.5	82.
38.0	PITCH AND YAW CONTROL	93986.	8.7	987.8	81.
45.0	P52 IMU ALIGN	93984.	2.3	985.5	81.
45.0	ORIENT FOR PTC	93980.	4.1	981.4	80.
45.0	ESTABLISH ROLL	93979.	.4	981.0	80.
49.0	PITCH AND YAW CONTROL	93971.	8.0	973.0	80.
53.0	P52 IMU ALIGN	93969.	2.3	970.7	80.
53.7	MIDCOURSE CORRECTION NO 3 MNVR TO BURN ATT	93965.	4.1	966.6	79.
53.7	ATTITUDE HOLD	93964.	.7	966.0	79.
53.7	SPS BURN BUILD UP	93961.	.0	966.0	79.
53.7	STEADY STATE BURN 11	93936.	.0	965.9	79.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
53.7	TAILOFF	93894.	.9	965.1	79.
53.7	DAMP SHUT.DOWN TRANSIENT	93893.	1.1	964.0	79.
53.7	RCS TRIM TO 0.5 FPS ALLOW 1.5 FPS TRIM	93877.	16.2	947.8	78.
53.7	TV ALLOWANCE	93873.	4.0	943.8	77.
54.1	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	93869.	4.1	939.7	77.
54.1	ESTABLISH ROLL	93869.	.4	939.3	77.
54.5	PITCH AND YAW CONTROL	93861.	7.8	931.5	76.
62.0	PITCH AND YAW CONTROL	93853.	7.8	923.7	76.
69.5	P52 IMU ALIGN	93851.	2.3	921.4	76.
71.7	MIDCOURSE CORRECTION NO 4 MNVR TO BURN ATT	93847.	4.1	917.3	75.
71.7	ATT HOLD 0.5 DEG DB PGNCS	93846.	.4	916.9	75.
71.7	DEL VEL = NOM ZERO	93846.	.0	916.9	75.
72.1	ORIENT FOR COMM	93842.	4.1	912.8	75.
72.1	TV ALLOWANCE	93838.	4.0	908.8	74.
72.1	SEXTANT STAR CHECKING	93836.	2.3	906.5	74.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
74.5	LUNAR ORBIT INSERTION BURN 1 3-AXIS ORIENT PGNCS	93832.	4.1	902.4	74.
74.5	ATTITUDE HOLD	93831.	.4	902.0	74.
75.7	START TRANSIENT CONTROL	93830.	1.3	900.7	74.
76.5	LOI1, NO ULLAGE, NO TRIM	93827.	.0	900.7	74.
76.5	STEADY STATE BURN 11	70243.	.6	900.1	74.
76.5	TAILOFF	70203.	.0	900.1	74.
76.5	DAMP SHUT DOWN TRANSIENT	70202.	1.1	899.0	74.
76.5	REV 1 ATTITUDE HOLD	70200.	1.5	897.5	74.
76.5	ROLL 180 DEG FOR COMMUNICATIONS	70200.	.5	897.0	74.
76.7	MANEUVER TO LUNAR OBSERVATION ATTITU DE	70196.	3.4	893.6	73.
76.3	REV 2 ATTITUDE HOLD	70193.	3.0	890.6	73.
77.2	MANEUVER TO SLEEP ATT FOR COMM TEST	70190.	3.4	887.2	73.
78.5	ROLL TO IMPROVE LUNAR OBSERVATION	70190.	.4	886.8	73.
79.2	LOI 2 LPO CIRC MNVR TO BURN ATT	70186.	3.4	883.3	72.
79.2	ATTITUDE HOLD	70186.	.4	882.9	72.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
80.2	ULLAGE 2 JETS A AND C	70171.	15.3	867.7	71.
80.2	SPS BURN BUILD UP	70168.	.0	867.7	71.
80.2	STEADY STATE BURN 14.5 SEC PGNCS	69190.	.2	867.5	71.
80.2	TAILOFF	69150.	.0	867.5	71.
80.2	DAMP SHUTDOWN TRANSIENT	69149.	1.1	866.4	71.
80.2	REV 3 ATTITUDE HOLD	69146.	3.0	863.4	71.
80.3	ROLL FOR COMM	69146.	.4	863.0	71.
80.3	TV ALLOWANCE	69142.	4.0	859.0	70.
80.3	P52 IMU ALIGN	69138.	3.5	855.5	70.
81.0	MNVR TO LDMK TRKG ATT	69134.	3.5	852.0	70.
82.5	REV 4 ATTITUDE HOLD	69131.	3.0	849.0	70.
82.5	REORIENT TO SLEEP ATTITUDE	69128.	3.5	845.5	69.
84.4	REV 5 ATTITUDE HOLD	69125.	3.0	842.5	69.
86.4	REV 6 ATTITUDE HOLD	69122.	3.0	839.5	69.
88.3	REV 7 ATTITUDE HOLD	69119.	3.0	836.5	69.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
90.3	REV 8 ATTITUDE HOLD	69116.	3.0	833.5	68.
92.3	REV 9 ATTITUDE HOLD	69113.	3.0	830.5	68.
94.3	REV 10 ATTITUDE HOLD	69110.	3.0	827.5	68.
95.5	REORIENT FOR LDMK STG	69106.	3.5	824.0	68.
96.2	REV 11 ATTITUDE HOLD	69103.	3.0	821.0	67.
96.7	ORIENT TO UNDOCKING ATT, ROLLED 180 DEG	69100.	3.5	817.5	67.
96.7	ROLL 180 DEG	69098.	1.5	816.0	67.
97.0	YAW LEFT 14 DEG	69097.	1.9	814.1	67.
97.0	EXTRA ALLOCATION PRE-SEPARATION BASED OM APOLLO 9 DATA	69073.	23.9	790.2	65.
98.2	UNDOCK	38222.	4.7	785.5	64.
98.2	STATION KEEP FOR LM PHOTOGRAPHY	38212.	10.0	775.5	64.
98.2	REV 12 ATT HOLD IN MIN DB	38207.	5.2	770.3	63.
98.2	ROLL 180 DEG	38206.	.8	769.5	63.
98.7	ORIENT FOR SEP BURN	38204.	1.8	767.7	63.
98.7	RCS SEPARATION BURN 2.5 FPS	38193.	11.2	756.5	62.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
98.8	P20 ORIENTATION	38190.	3.1	753.4	62.
99.5	P20 MANEUVER (PITCH)	38187.	3.1	750.3	61.
99.6	P20 ORIENTATION MANEUVER (PITCH) TRIM TRKG ATT POST DOI	38184.	3.1	747.2	61.
100.2	REORIENT PITCH AND ROLL FOR COMM	38182.	1.9	745.3	61.
100.2	REV 13 ATT HOLD IN MIN DB	38177.	5.2	740.1	61.
100.7	MANEUVER TO TRACK PHASING BURN	38173.	3.3	736.8	60.
100.8	TRIM TRKG ATT POST PHASING	38170.	3.0	733.8	60.
102.2	REV 14 ATT HOLD IN MIN DB	38165.	5.2	728.6	60.
102.5	P40 ORIENT TO BACK UP LM INSERTION BURN	38162.	3.1	725.5	59.
103.0	P20 TRIM TO TRKG ATT	38159.	3.1	722.4	59.
103.5	MANEUVER TO BACKUP CSI	38156.	3.1	719.4	59.
103.6	TRIM TO TRKG ATT POST CSI	38153.	3.2	716.2	59.
104.1	REV 15 ATT HOLD IN MIN DB	38147.	5.2	711.0	58.
104.7	TRIM TO TRK LM POST PLANE CHANGE	38144.	3.2	707.8	58.
105.0	MANEUVER TO BACK UP TPI	38141.	3.2	704.6	58.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
105.0	TRIM ATT TO TRACK LM POST TPI	38138.	3.1	701.6	58.
105.4	ORIENT TO MCC1 ATT	38135.	3.1	698.4	57.
105.4	TRIM TO TRKG ATT	38132.	3.2	695.2	57.
105.4	ORIENT TO MCC2 ATT	38129.	3.1	692.1	57.
105.4	TRIM TO TRKG ATT	38126.	3.1	689.0	56.
106.0	STATION KEEP FOR LM PHOTOGRAPHY	38116.	10.0	679.0	56.
106.0	REORIENT FOR DOCKING	38112.	3.1	675.9	55.
106.1	REV 16 ATT HOLD IN MIN DB	38107.	5.2	670.7	55.
106.1	MAINTAIN BORESIGHT	38105.	1.7	669.0	55.
106.1	EXTRA ALLOCATION DURING RENDEZVOUS BASED ON APOLLO 9 DATA	38090.	15.0	654.0	54.
106.3	CSM ACTIVE STATION KEEP AND DOCK	45749.	25.1	628.9	52.
106.3	EXTRA ALLOCATION POST DOCKING BASED ON APOLLO 9 DATA	45720.	29.0	599.9	49.
106.7	MANEUVER TO APS BTD ATT 0.5 DEG/SEC	45717.	3.2	596.7	49.
108.1	REV 17 ATTITUDE HOLD	45714.	3.0	593.7	49.
108.6	ORIENT FOR SEP BURN	45711.	3.2	590.5	48.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
108.7	JETTISON LM 2FPS	38016.	10.9	579.5	48.
108.7	MNVR TO OBSERVE LM	38014.	1.8	577.8	47.
108.7	TV ALLOWANCE	38010.	4.0	573.8	47.
108.7	MANEUVER TO SLEEP ATTITUDE	38009.	1.8	572.0	47.
110.0	REV 18 ATTITUDE HOLD	38006.	3.0	569.0	47.
112.0	REV 19 ATTITUDE HOLD	38003.	3.0	566.0	46.
114.0	REV 20 ATTITUDE HOLD	38000.	3.0	563.0	46.
116.0	REV 21 ATTITUDE HOLD	37997.	3.0	560.0	46.
117.9	REV 22 ATTITUDE HOLD	37994.	3.0	557.0	46.
117.9	MANEUVER FOR PHOTOGRAPHY 2 MANEUVERS	37991.	2.6	554.4	45.
119.9	REV 23 ATTITUDE HOLD	37988.	3.0	551.4	45.
119.9	MNVR TO SUBSOLAR PT	37986.	1.7	549.7	45.
120.5	REV 24 IMU ALIGN	37985.	.8	548.9	45.
121.9	REV 24 ATTITUDE HOLD	37982.	3.0	545.9	45.
122.5	REORIENT FOR LANDMARKS 3 TIMES PER REV	37979.	3.6	542.4	44.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
122.5	ROLL TO ACQUIRE MSFN	37979.	.3	542.0	44.
123.9	REV 25 ATTITUDE HOLD	37976.	3.0	539.0	44.
124.0	REV 25 IMU ALIGN	37975.	.8	538.3	44.
124.5	REORIENT FOR LANDMARKS 3 TIMES PER REV	37971.	3.6	534.7	44.
124.5	ROLL TO ACQUIRE MSFN	37971.	.3	534.4	44.
125.8	REV 26 ATTITUDE HOLD	37968.	3.0	531.4	44.
126.0	REV 26 IMU ALIGN	37967.	.8	530.6	43.
126.5	REORIENT FOR LANDMARKS 3 TIMES PER REV	37964.	3.6	527.0	43.
126.5	ROLL TO ACQUIRE MSFN	37963.	.3	526.7	43.
127.8	REV 27 ATTITUDE HOLD	37960.	3.0	523.7	43.
128.0	REV 27 IMU ALIGN	37959.	1.0	522.8	43.
128.0	ORIENT TO REST ATTITUDE	37958.	1.7	521.0	43.
128.0	REV 28 ATT HOLD	37955.	3.0	518.0	42.
128.0	REV 29 ATT HOLD	37952.	3.0	515.0	42.
131.9	MNVR FOR PHOTOGRAPHY	37950.	1.7	513.3	42.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
133.0	MNVR FOR PHOTOGRAPHY	37948.	1.7	511.6	42.
133.9	MNVR TO LDMK STG ATT	37946.	1.7	509.9	42.
133.9	ROLL TO ACQUIRE MSFN	37946.	.3	509.5	42.
133.9	REV 30 ATT HOLD	37943.	3.0	506.5	42.
135.9	MNVR TO PHOTO ATTITUDE	37941.	1.7	504.8	41.
136.0	YAW 2X FOR PHOTOS	37939.	2.1	502.7	41.
136.0	REV 31 ATT HOLD	37936.	3.0	499.7	41.
136.3	MNVR TO TEI ATT (ROLLED 180 DEG)	37935.	1.7	498.0	41.
136.3	ORIENT FOR TEI ROLL 180 DEG	37934.	.5	497.5	41.
136.3	- ATTITUDE HOLD	37934.	.4	497.1	41.
136.3	ULLAGE 2 JETS B AND D	37918.	15.2	481.9	39.
137.3	SPS BURN BUILD UP	37915.	.0	481.9	39.
137.3	STEADY STATE BURN 136 SEC PGNCS	28751.	.3	481.6	39.
137.3	TAILOFF	28711.	.0	481.6	39.
137.3	DAMP SHUTDOWN TRANSIENT	28710.	1.1	480.5	39.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
137.3	TV ALLOWANCE	28706.	4.0	476.5	39.
138.4	P52 IMU ALIGN	28704.	1.5	475.0	39.
138.5	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	28704.	.6	474.3	39.
138.5	ESTABLISH ROLL	28703.	.2	474.2	39.
138.5	PITCH AND YAW CONTROL	28692.	11.0	463.2	38.
150.0	P52 IMU ALIGN	28691.	1.5	461.7	38.
150.0	CISLUNAR NAVIGATION 5 STAR SETS	28685.	5.9	455.8	37.
150.0	CISLUNAR NAV SIGHTINGS TOTAL OF 9 S ETS	28681.	4.2	451.5	37.
150.0	ATT CONTROL	28679.	2.2	449.4	37.
152.3	MIDCOURSE CORRECTION NO 5 MNVR TO BURN ATT	28677.	1.5	447.9	37.
152.3	ATTITUDE HOLD	28677.	.3	447.6	37.
152.3	DEL VEL = NOM ZERO	28677.	.0	447.6	37.
152.3	TV ALLOWANCE	28673.	4.0	443.6	36.
153.0	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	28672.	.6	443.0	36.
153.0	EST. 0.3 DEG/SEC ROLL	28672.	.2	442.8	36.

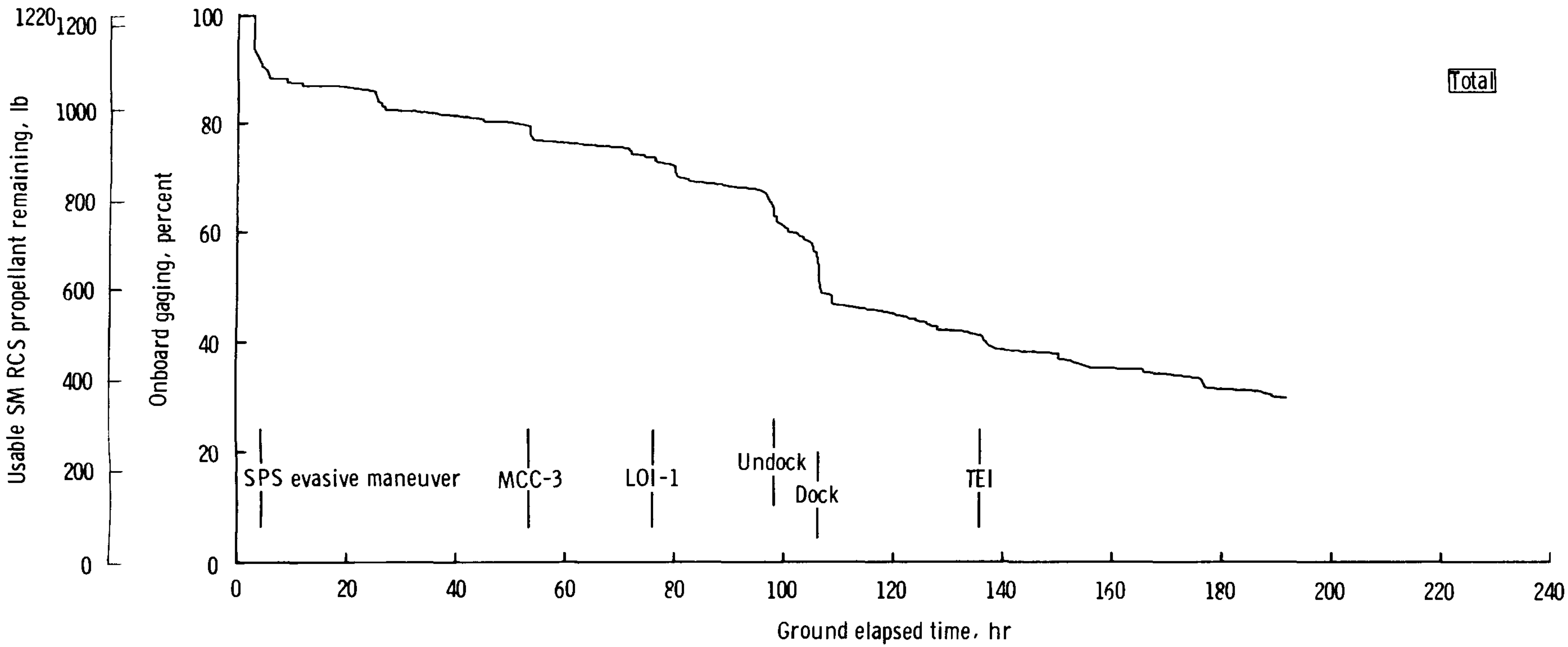
TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM_RCS USED (LBS)	SM_RCS LEFT (LBS)	SM_RCS LEFT (%)
153.0	PITCH AND YAW CONTROL	28660.	12.0	430.8	35.
156.0	P52 IMU ALIGN	28659.	1.5	429.3	35.
165.0	CISLUNAR NAVIGATION STAR/LUNAR HORIZON ORIENT	28653.	5.9	423.4	35.
165.5	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	28652.	.6	422.8	35.
165.5	ESTABLISH ROLL	28652.	.2	422.6	35.
165.5	PITCH AND YAW CONTROL	28646.	6.0	416.6	34.
171.0	P52 IMU ALIGN	28644.	1.5	415.1	34.
171.0	NAV SIGHTINGS	28644.	.7	414.5	34.
172.0	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	28643.	.6	413.8	34.
172.0	EST. 0.3 DEG/SEC ROLL	28643.	.2	413.6	34.
172.0	PITCH AND YAW CONTROL	28639.	4.0	409.6	34.
175.0	P52 IMU ALIGN	28637.	1.5	408.1	33.
176.2	MIDCOURSE CORRECTION NO 6 MNVR TO BURN ATT	28636.	1.5	406.6	33.
176.2	ATT HOLD .5 DEG DB PGNCS	28636.	.4	406.2	33.
176.2	RCS -X TRANS 5 FPS	28619.	16.8	389.5	32.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Concluded

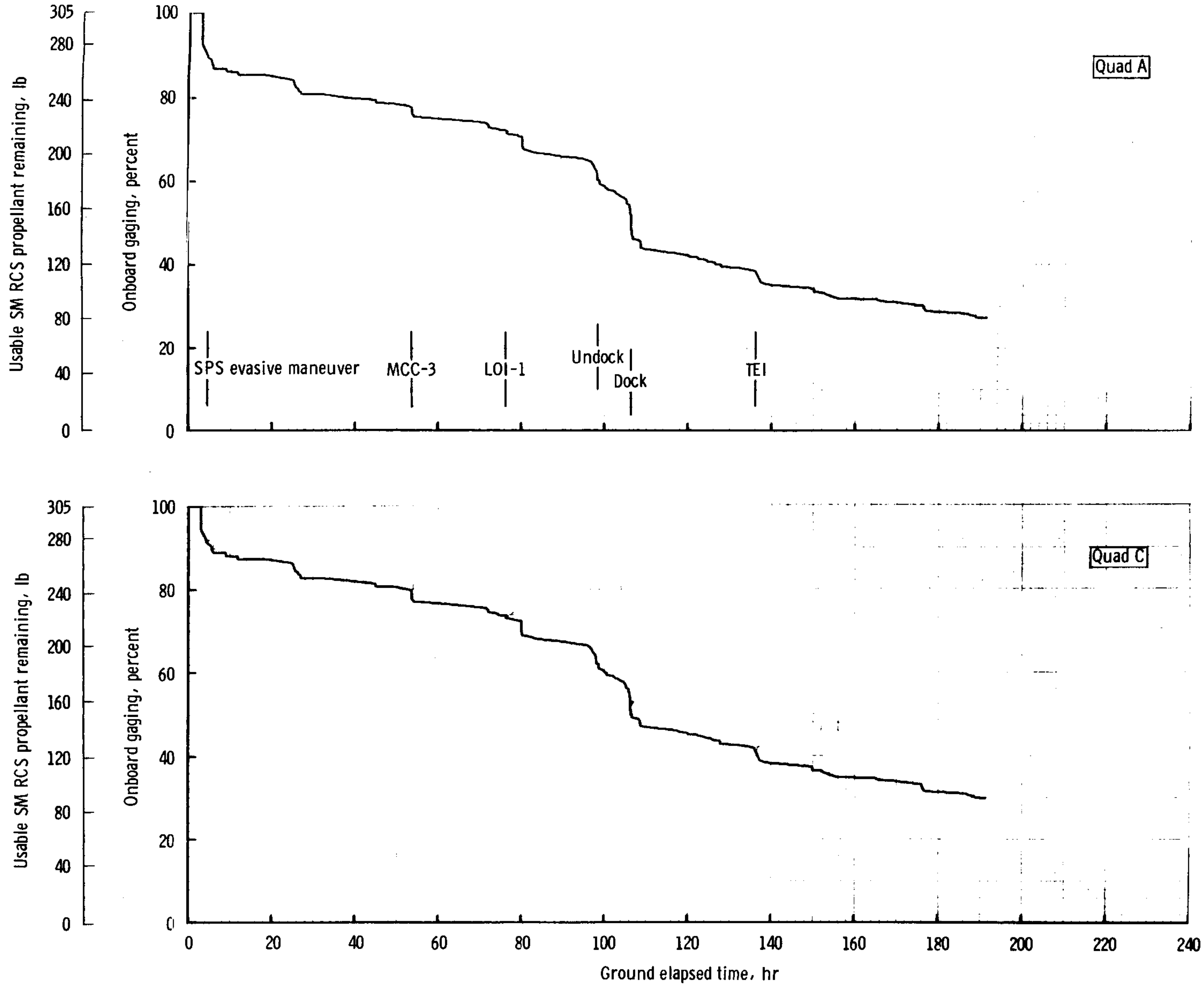
TIME (HR)	EVENT	S/C WT (LBS)	SM-RCS USED (LBS)	SM-RCS LEFT (LBS)	SM-RCS LEFT (%)
176.7	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	28618.	.6	388.9	32.
176.7	ESTABLISH ROLL	28618.	.2	388.7	32.
176.7	PITCH AND YAW CONTROL	28609.	9.0	379.7	31.
187.0	P52 IMU ALIGN	28607.	1.5	378.2	31.
187.0	TV ALLOWANCE	28603.	4.0	374.2	31.
188.3	MIDCOURSE CORRECTION NO 7 MNVR TO BURN ATT	28602.	1.5	372.6	31.
188.3	ATT HOLD .5 DEG DB PGNCS	28602.	.3	372.4	31.
188.3	DEL VEL = NOM ZERO	28602.	.0	372.4	31.
189.0	P52 IMU ALIGN	28600.	1.6	370.8	30.
189.0	MANEUVER TO REENTRY ATTITUDE	28599.	1.5	369.3	30.
189.0	ATTITUDE HOLD 0.2 DEG DB SCS	28598.	.8	368.5	30.
189.0	PITCH TO ACQUIRE HORIZON	28597.	.7	367.8	30.
189.0	YAW 45 DEG	28596.	.7	367.2	30.
189.0	ATT HOLD .5 DEG DB PGNCS	28596.	.4	366.8	30.
191.6	CM/SM SEPARATION DELTA VEL=3 FPS	16213.	8.5	358.3	29.

[a]Except for mission duty cycle mixture ratio shift, (table 2-II), this propellant is usable.



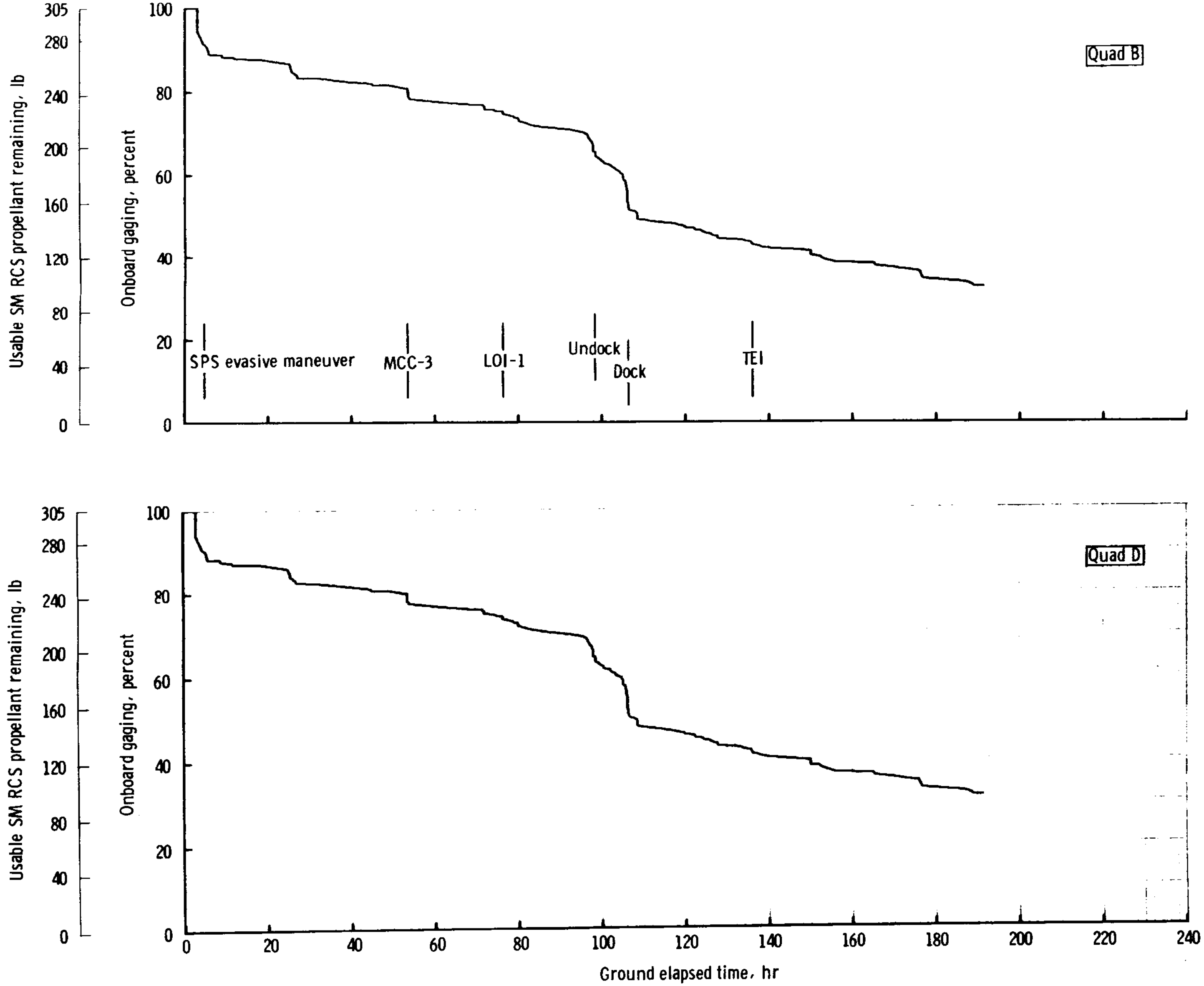
(a) Total.

Figure 2.1. SM RCS propellant profile.



(b) Quads A and C.

Figure 2.1. - Continued.



(c) Quads B and D.

Figure 2.1.- Concluded.

3.0 CSM - ACTIVE RESCUE OF LM

The critical consumable for a CSM-active rescue of a disabled LM is the SM RCS propellant. The rescue situation analyzed here is one in which the CSM must begin rescue with the insertion burn. The ΔV required from the SPS (320.5 fps) is well within the 900 fps mission flexibility ΔV available (section 4.0: The SPS Analysis).

The minimum quantity of SM RCS propellant remaining at undocking for initiation of the nominal LM-active rendezvous must be sufficient to provide for a CSM-active rescue of a nonpropulsive LM and for the transearth phase of the mission. Two rescue situations are considered here.

1. The LM is unable to perform insertion, CSI, CDH, and TPI, but the malfunction does not preclude use of the LM RCS for the braking phase.

2. Same as above, but the LM is also unable to perform the braking.

Based on an appraisal of the likelihood of various failure modes, it is felt that case II is unduly conservative, and it has been recommended that case I be the redline requirement for the decision of whether or not to commit to the rendezvous. Case II is included for reference purposes.

The propellant budget for the CSM support of the nominal LM-active rendezvous has been increased considerably over the budget of reference 6. This increase reflects Apollo 9 postflight results and Apollo 10 simulator data. If a CSM rescue occurs, this propellant would be available for those activities common to the nominal CSM support of the LM-active rendezvous and the CSM-active rescue.

Above the nominal rendezvous usage, the propellant quantities listed in table 3-I for case I must be reserved for the rescue situation. Because the total allocation for the nominal CSM support of the LM-active rendezvous is 161.3 pounds (table 2-III, undock through dock) with an extra allocation for the rescue of 190.2 pounds (table 3-I, case I), the total propellant available for the rescue rendezvous is 351.5 pounds (of which 161.3 lb are included in the nominal budget) with the LM doing the braking.

The minimum SM RCS propellant requirements for rescue and safe return are summarized in tables 3-II and 3-III. Case I is recommended to establish a mission redline. It is based on a rescue that includes LM-active braking followed by an immediate return to earth (deleting subsequent lunar orbit activities and nonessential transearth TV allocations).

Case II shows the margin for the LM-active braking followed by completion of the nominal mission. Case III is based on the CSM braking with immediate return. Case IV shows the CSM braking completion of the nominal mission. As shown in table 3-III, all but case IV show a positive margin at undock.

TABLE 3-I.- CSM ACTIVE RESCUE OF NONPROPULSIVE LM, SM RCS USAGE ABOVE NOMINAL CSM SUPPORT OF LM-ACTIVE RENDEZVOUS

	Propellant used for Case I (LM braking), lb	Propellant used for Case II (CSM braking), lb
RCS usage for SPS insertion burn		
Ullage, four jets, 10 sec plus 2 sec overlap	17.3	Same as case I
Moment control	2.0	
RCS usage for SPS CSI		
Ullage	17.3	
Moment control	2.0	Same as case I
Trim[a]	10.4	
RCS usage for SPS CDH		
Ullage	17.3	
Moment control	2.0	Same as case I
Trim[a]	13.0	
RCS usage for SPS TPI		
Ullage	17.3	
Moment control	2.0	Same as case I
Trim[a]	10.4	
Subtotal	111.0	111.0
Braking	--	150
MCC's and LOS control[b]	69.2	69.2
Mixture ratio allowance	10.0	10.0
Total	190.2	340.2

[a]Reference 7.

[b]Reference 8.

TABLE 3-II.- MINIMUM SM RCS PROPELLANT REQUIRED FOR RESCUE AND RETURN

[Case I, LM braking]

Mission phase	Minimum propellant required, lb
Undock	581.2
Postinsertion	497.2
Post-CSI	461.4
Post-CDH	429.1
Post-TPI	384.6
Postdocking	229.7
TEI	166.8
CM/SM separation	0.

TABLE 3-III.- SM RCS MARGIN AT UNDOCKING WITH CSM-ACTIVE RESCUE

Case no.	Active vehicle for braking	Mission activities post-rendezvous	Propellant margin at undock, lb
I	LM	Immediate return	209.0
II	LM	Nominal mission	130.7
III	CSM	Immediate return	59.0
IV	CSM	Nominal mission	-19.3

4.0 THE SPS ANALYSIS

The budget presented in table 4-I is for a May 18 launch, 72° launch aximuth, first opportunity injection, and fast earth return. The assumptions used to prepare this budget are presented in table 4-II. Engine performance characteristics are taken from reference 1, and the ΔV requirements are taken from reference 9.

Note that the mission flexibility ΔV of 900 fps has been used in addition to the fast return. In real time, however, it is highly likely that a slower return would be performed if the 900 fps had been used prior to TEI (e.g., for LM rescue). Hence, the margin of 762 pounds shown in table 4-I assumes both a fast return and use of the 900 fps contingency ΔV.

TABLE 4-I.- SPS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded[a]	--	40 808.7
Trapped and unavailable[a]	441.4	40 367.3
Outage	78.5	40 288.8
Unbalance meter bias	100.0	40 188.8
Available for ΔV	--	40 188.8
Required for ΔV		
TLMC (120 fps)[b]	1139.7	39 049.1
LOI-1 (2978.35 fps)	23650.8	15 398.3
LOI-2 (138.5 fps)	952.9	14 445.4
TEI[c] (3622.5 fps)	11101.4	3 344.0
Nominal remaining		3 344.0
Mission flexibility ΔV (900 fps)	2234.1	1 109.9
Dispersions (-3σ)	348.4	761.5
Propellant margin		761.5

[a]Reference 3.

[b]Includes 19.7 fps for evasive burn and 57.0 fps for nominal MCC-1.

[c]Approximately 9100 lb are required for 1-day later return.

TABLE 4-II.- ASSUMPTIONS FOR THE SPS ANALYSIS

1. Launch was on May 18, 1969 at a 72° launch azimuth with a first opportunity injection and a fast earth return.

2. Each SPS engine start used 14.4 lb of propellant in non-propulsive losses.

3. Spacecraft weight:

CM, lb	12 276.8
SM, lb	10 641.8
SLA ring, lb	98.0
Tanked SPS, lb	40 606.4
LM (unmanned), lb	30 848.8
Spacecraft at TLC, lb	94 471.8

4. SM RCS, EPS, and ECS weight losses

Mission Period	
Lift-off to evasive maneuver	97.9
Evasive maneuver to MCC-1	53.4
MCC-1 to LOI-1	404.8
LOI-1 to LOI-2	26.3
LOI-2 to TEI	231.8

5. CM equipment jettisoned with the ascent stage in lunar orbit was 193.4 lb.

5.0 THE LM RCS PROPELLANT ANALYSIS

TABLE 5-I.- GROUND RULES AND ASSUMPTIONS

1. Data for the LM RCS propellant requirements were obtained from reference 2.

2. All orientation maneuvers were assumed to be made at 2.0 deg/sec.

3. All orientation maneuvers were assumed to be three-axis maneuvers.

4. Line of sight with the CSM was assumed to be maintained in the AGS minimum impulse mode.

TABLE 5-II.- LM RCS PROPELLANT SUMMARY

Description	Propellant, lb	
	Required	Remaining
Loaded		633.0
Trapped	40.6	
Gaging inaccuracy and loading tolerance	39.5	
Mixture ratio uncertainty	17.0	
Usable		535.9
Nominal mission requirement	318.2	
Nominal remaining		217.7

TABLE 5-III.- ONBOARD READING OF RCS PROPELLANT REMAINING

Event	Percentage of propellant remaining in system A	Percentage of propellant remaining in system B
Post-DOI	96	94
Postphasing	93	89
Postinsertion	85	82
Post-CSI	79	75
Post-CDH	75	71
Post-TPI	69	65
Postbraking	54	51
Postdocking	51	47

TABLE 5-IV.- LM RCS PROPELLANT BUDGET

TIME HRS	M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (%)
0	0	OUTPUT PROPELLANT LOADINGS	31321.	.0	633.0	100.
97	15	RCS HOT FIRE	31252.	5.0	628.0	99.
98	10	UNDOCKING	31252.	.0	628.0	99.
98	15	MNVR FOR INSP AND FOR FLY	31229.	10.0	618.0	98.
98	45	RR LOCK ON CHECK	31225.	3.9	614.1	97.
98	50	IMU REALIGN STAR 1	31221.	3.9	610.1	96.
98	50	IMU REALIGN STAR 2	31217.	3.9	606.2	96.
98	50	IMU REALIGN STAR 3	31213.	3.9	602.3	95.
99	27	MNVR TO BURN ATTITUDE	31209.	3.9	598.4	95.
99	27	ATTITUDE HOLD	31209.	.5	597.9	94.
99	33	2 JET ULLAGE	31203.	5.9	592.0	94.
99	33	DESCENT ORBIT INSERT. BURN	30975.	.0	592.0	94.
99	33	MOMENT CONTROL	30968.	7.0	585.0	92.
99	33	ATTITUDE HOLD	30968.	.5	584.5	92.
99	35	RR LOCK ON	30964.	3.9	580.6	92.
99	35	MAINTAIN RR TRACKING	30962.	1.4	579.2	92.
100	0	PITCH DOWN 90 DEG.	30960.	1.8	577.4	91.
100	0	YAW LEFT 180 DEG.	30959.	1.5	575.9	91.
100	0	YAW RIGHT 180 DEG.	30957.	1.5	574.4	91.
100	35	PITCH DOWN 90 DEG.	30957.	.5	573.9	91.
100	40	MNVR TO BURN ATTIUTDE	30953.	3.9	570.0	90.
100	40	ATTITUDE HOLD	30953.	.5	569.5	90.
100	46	2 JET ULLAGE	30947.	5.9	563.6	89.
100	46	DPS PHASING BURN	30329.	.0	563.6	89.
100	46	MOMENT CONTROL	30315.	1.5	562.1	89.

TABLE 5-IV.- LM RCS PROPELLANT BUDGET - Continued

TIME HRS M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (%)
100 46	ATTITUDE HOLD	30314.	.5	561.6	89.
100 46	YAW	30313.	1.5	560.1	88.
100 46	PITCH	30311.	1.8	558.3	88.
100 50	RR LOCK ON	30307.	3.9	554.5	88.
100 50	MAINTAIN RR TRACKING	30306.	.7	553.8	87.
101 0	IMU REALIGN STAR 1	30302.	3.9	549.9	87.
101 0	IMU REALIGN STAR 2	30299.	3.9	546.1	86.
101 0	COAS CALIBRATION	30295.	3.8	542.2	86.
101 10	RR LOCK ON	30291.	3.8	538.4	85.
101 10	MAINTAIN RR TRACKING	30289.	2.0	536.3	85.
102 10	RR LOCK ON	30285.	3.8	532.5	84.
102 10	MAINTAIN RR TRACKING	30284.	1.4	531.1	84.
102 33	ORIENT FOR STAGING	30280.	3.8	527.3	83.
102 33	STAGING	8378.	.0	527.3	83.
102 33	START STAGING	8377.	1.9	525.4	83.
102 33	COMPLETE STAGING	8375.	1.9	523.6	83.
102 37	MNVR TO BURN ATTITUDE	8374.	.9	522.7	83.
102 37	ATTITUDE HOLD	8372.	2.2	520.5	82.
102 43	2 JET ULLAGE	8369.	2.8	517.7	82.
102 43	MOMENT CONTROL INSERTION BURN	8197.	.9	516.8	82.
102 43	NULL DVEL 1FPS XAXIS	8196.	.9	515.9	82.
102 43	NULL DVEL 1FPS YAXIS	8195.	1.1	514.8	81.
102 43	NULL DVEL 1FPS ZAXIS	8193.	1.0	513.7	81.
102 43	YAW	8193.	.3	513.4	81.
102 43	PITCH	8193.	.2	513.2	81.

TABLE 5-IV.- LM RCS PROPELLANT BUDGET - Continued

TIME HRS	M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (%)
102	43	ATTITUDE HOLD	8191.	2.3	510.9	81.
102	50	IMU REALIGN STAR 1	8190.	.8	510.0	81.
102	50	IMU REALIGN STAR 2	8189.	.8	509.2	80.
102	50	IMU REALIGN STAR 3	8188.	.8	508.3	80.
103	0	RR LOCK ON	8187.	.8	507.5	80.
103	0	MAINTAIN RR TRACKING	8180.	6.8	500.7	79.
103	27	MNVR TO BURN ATTITUDE	8180.	.8	499.8	79.
103	27	ATTITUDE HOLD	8179.	.9	499.0	79.
103	33	CSI RCS BURN	8133.	14.2	484.7	77.
103	33	ATTITUDE HOLD	8131.	2.3	482.4	76.
103	37	RR LOCK ON	8130.	.8	481.5	76.
103	37	MAINTAIN RR TRACKING	8125.	4.6	477.0	75.
104	1	PLANE CHANGE	8123.	2.0	475.0	75.
104	5	MAINTAIN RR TRACKING	8112.	11.4	463.6	73.
104	25	MNVR TO BURN ATTITUDE	8111.	.8	462.7	73.
104	25	ATTITUDE HOLD	8109.	2.2	460.5	73.
104	31	CDH +Z BURN	8105.	3.4	457.1	72.
104	31	ATTITUDE HOLD	8103.	2.4	454.7	72.
104	35	MAINTAIN LOS	8095.	8.0	446.7	71.
105	9	TPI RCS BURN	8070.	24.7	422.0	67.
105	9	ATTITUDE HOLD	8068.	2.4	419.7	66.
105	12	ORIENT TO ATTITUDE	8067.	.8	418.8	66.
105	12	MAINTAIN LOS	8063.	4.6	414.3	65.
105	40	MCC AND BRAKING	8013.	49.1	365.1	58.
105	40	ATTITUDE HOLD	8011.	2.4	362.8	57.

TABLE 5-IV.- LM RCS PROPELLANT BUDGET - Concluded

TIME HRS M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (&)
105 40	ATTITUDE MNVRS AND LCS CONTROL	7985.	26.0	336.8	53.
105 55	FOR FLYING	7973.	12.0	324.8	51.
106 20	LM CONTROL DURING CSM ACTIVE D OCK.	7963.	10.0	314.8	50.
107 0	TRANSFER EQP TO LM	8243.	.0	314.8	50.
107 0	UNDOCKING	7778.	.0	314.8	50.
108 39	APS BURN TO DEPLE.	5475.	.0	314.8	50.

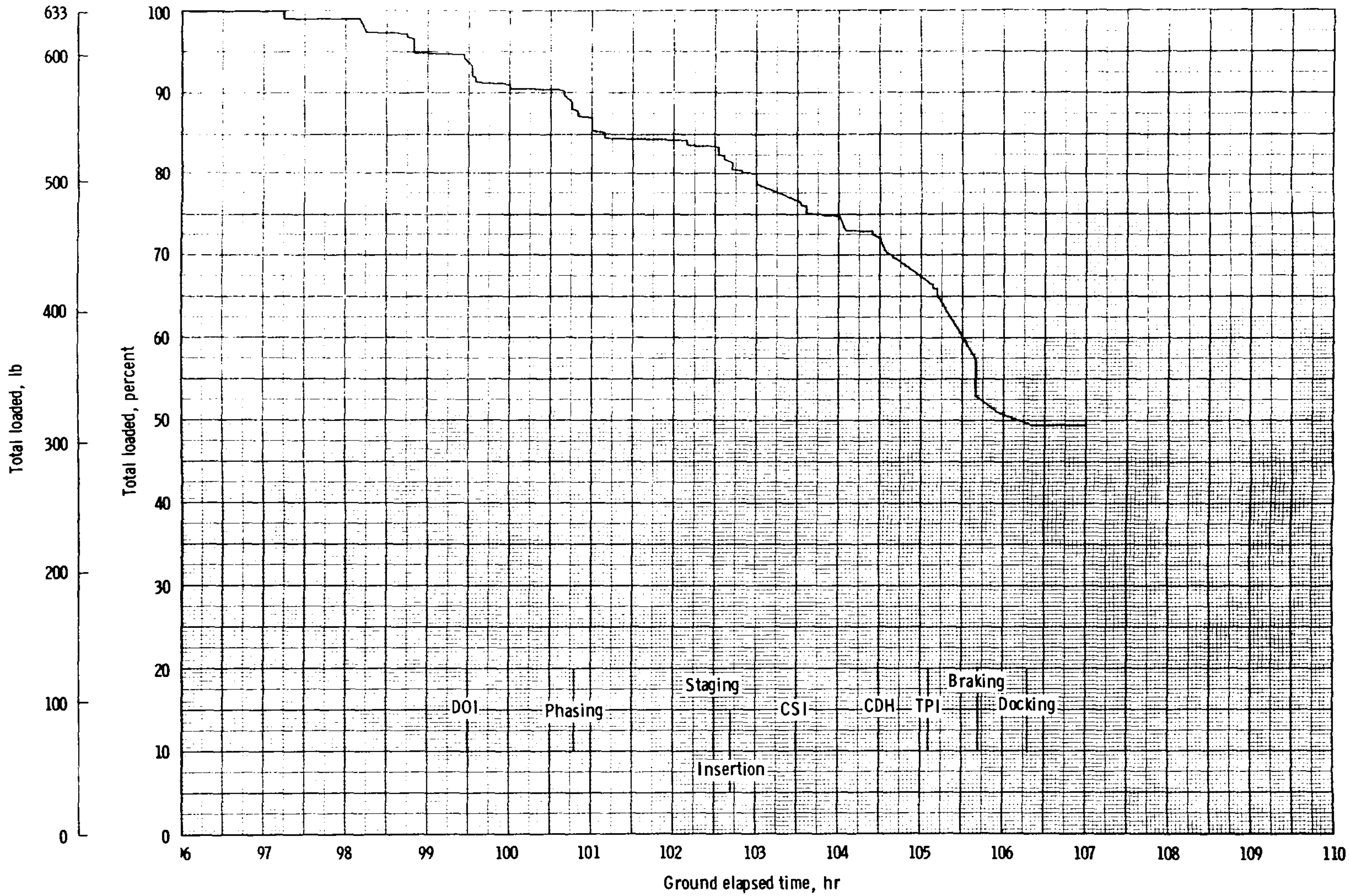


Figure 5-1. - LM RCS propellant profile.

6.0 THE DPS ANALYSIS

The assumptions for the DPS analysis are presented in table 6-I, and the DPS propellant requirements are shown in table 6-II. Propellant loads are taken from reference 3. Burn requirements reflect the following thrust profiles: DOI performed at 10 percent thrust for 15 seconds and at 40 percent thrust for 14.9 seconds; phasing performed at 10 percent thrust for 26 seconds and at F.T.P. for 19.3 seconds. There is a propellant margin of 16 865 pounds.

TABLE 6-I.- ASSUMPTIONS FOR THE DPS ANALYSIS

1. Mixture ratio = 1.597 ± 0.0141 (ref. 10).

2. Propellant cost for engine and valve operation is 8.6 lb per engine start.

3. Buildup and tailoff cost is 19.15 lb of propellant per burn.

4. Propellant flow rates for various throttle settings were taken from reference 2.

TABLE 6-II.- DPS PROPELLANT SUMMARY

	Propellant required, lb	Propellant remaining, lb
Loaded[a]		18 264.2
Trapped[a]	198.2	18 066.0
3σ outage	125.2	17 940.8
Available for ΔV		17 940.8
Required for ΔV[b]		
DOI, 71.1 fps, 29.9 sec[c]	308.2	17 632.6
Phasing, 195.6 fps, 45.3 sec[d]	767.8	16 864.8
Propellant margin		16 864.8

[a]Reference 3.

[b]Includes nonpropulsive usage and buildup/tailoff usage.

[c]15 seconds at 10% thrust and 14.9 seconds at 40% thrust.

[d]26 seconds at 10% thrust and 19.3 seconds at F.T.P.

7.0 THE APS ANALYSIS

The assumptions for the APS analysis are presented in table 7-I. The APS propellant budget is presented in table 7-II. The data for usable propellant were taken from reference 3 and assume a 50 percent APS propellant loading. The CSI was performed with RCS/APS interconnect for 22 seconds. Because of the APS burn to depletion, there is a zero APS propellant margin.

TABLE 7-I.- ASSUMPTIONS FOR THE APS ANALYSIS

1. I_{sp} = 308.5 ± 3.6 seconds (ref. 2).

2. APS propellant tanks are 50% loaded.

3. Ascent stage at earth lift-off weighs 7959 lb (unmanned).

4. LM RCS and ascent stage EECOM weight loss is 122.6 lb prior to insertion.

5. Mixture ratio = 1.587 ± 0.018 (ref. 2).

6. Engine and valve operation uses 3.6 lb of propellant per APS burn.

TABLE 7-II.- APS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded[a]		2631.7
Trapped[b]	48.9	2582.8
Available for ΔV		2582.8
Required for ΔV		
Insertion, 206.9 fps, 15.4 sec	174.8	2408.0
CSI, 50.3 fps, 22 sec through interconnect	32.3	2375.7
Burn to depletion	2375.7	0
Propellant margin		0

[a]Reference 3.

[b]Does not include trapped in feed lines and heat exchanger, which is considered usable for depletion burn.

8.0 THE CSM EPS ANALYSIS

The power levels of each component were obtained from reference 1; the cryogenic loading data were obtained from reference 3. Cislunar heater cyclic rates were used for TLC and TEC.

The EPS profile presented in figure 8-1 indicates that no serious problems exist. Because the May 18 mission is only 192 hours, there are ample cryogenics (figs. 8-2 and 8-3) for mission completion. However, a worst case tank failure could occur at TEI minus 18 hours (REV 24) which would increase the time on one tank. REV 24 was determined to be the worst case point because at this point there is not enough SPS ΔV available to return to earth earlier than the nominal 192 hours and still land in the primary landing area. Therefore, a nominal power-down of the spacecraft to 55 amperes for TEC insures a safe return to earth. The total DC energy accumulated throughout the mission is presented in figure 8-4. The CM bus voltage profile is presented in figure 8-5 and indicates that no voltage limits are violated.

The metabolic O_2 requirements were altered to 0.197 lb/hr, rather than 0.23 lb/hr, based on postflight analyses of Apollo 7 and 8. This alteration corresponds to approximately 400 Btu/hr as compared with 467 Btu/hr.

The 45 A-h rating mentioned in assumption 3 also was based on postflight testing of the entry and postlanding batteries.

8-I.- ASSUMPTIONS FOR THE CSM EPS ANALYSIS

1. The system was assumed to operate with three fuel cells and two inverters.

2. The fuel cells were purged every 900 A-h.

3. Three entry and postlanding batteries were considered available to supply the total spacecraft power required for entry, parachute descent and postlanding time. Each battery was assumed to have a 40 A-h capacity until splashdown, at which time the capacity was uprated to 45 A-h.

4. Two batteries were considered to be in parallel with the fuel cells during ascent and for each SPS maneuver.

5. No cryogenic venting was assumed.

6. The EPS hydrogen consumption rate (lb/hr) = $0.00257 \times I_{fc}$.

7. The EPS oxygen consumption rate (lb/hr) = $7.936 \times \dot{H}_2$.

8. An SPS evasive maneuver and two SPS midcourse corrections were assumed.

9. Six battery charges were assumed: three on battery A and three on battery B.

10. Five percent uncertainty in the EPS profile is included in the cryogenic requirements.

TABLE 8-II.- CRYOGENIC SUMMARY

Description	H_2		O_2	
	Required	Remaining	Required	Remaining
Loaded (two tanks)		58.60		660.20
Residual	2.32	56.28	13.0	647.20
Instrumentation error	1.53	54.75	17.5	629.70
Available for mission planning		54.75		629.70
Prelaunch requirements				
t minus 28 hr to t minus 12 hr at load of 10.8 amperes	.45	54.30	3.59	626.11
Vent allowance (H_2 = 0.055 lb/hr), (O_2 = 0.65 lb/hr)	.88	53.42	10.40	615.71
t minus 12 hr to t minus 9 hr at load of 60 amperes	.46	52.96	3.67	612.04
t minus 9 hr to t minus 2 hr (includes 6 hr hold) at load of 45 amperes	1.50	51.46	11.93	600.11
Crew ingress at t minus 3 hr (0.196 lb/hr)	--	--	.59	599.52
t minus 2 hr at 75 amperes	.39	51.07	3.06	596.46
Mission requirements				
EPS	36.12	14.95	260.86	335.60
ECS (includes CSM LM requirements)	--	--	95.62	239.98
Uncertainties				
5% uncertainty in EPS	1.81	13.14	13.02	226.96
Launch window 4.5 hr	.87	12.27	7.80	219.16
Margin	--	12.27	--	219.16

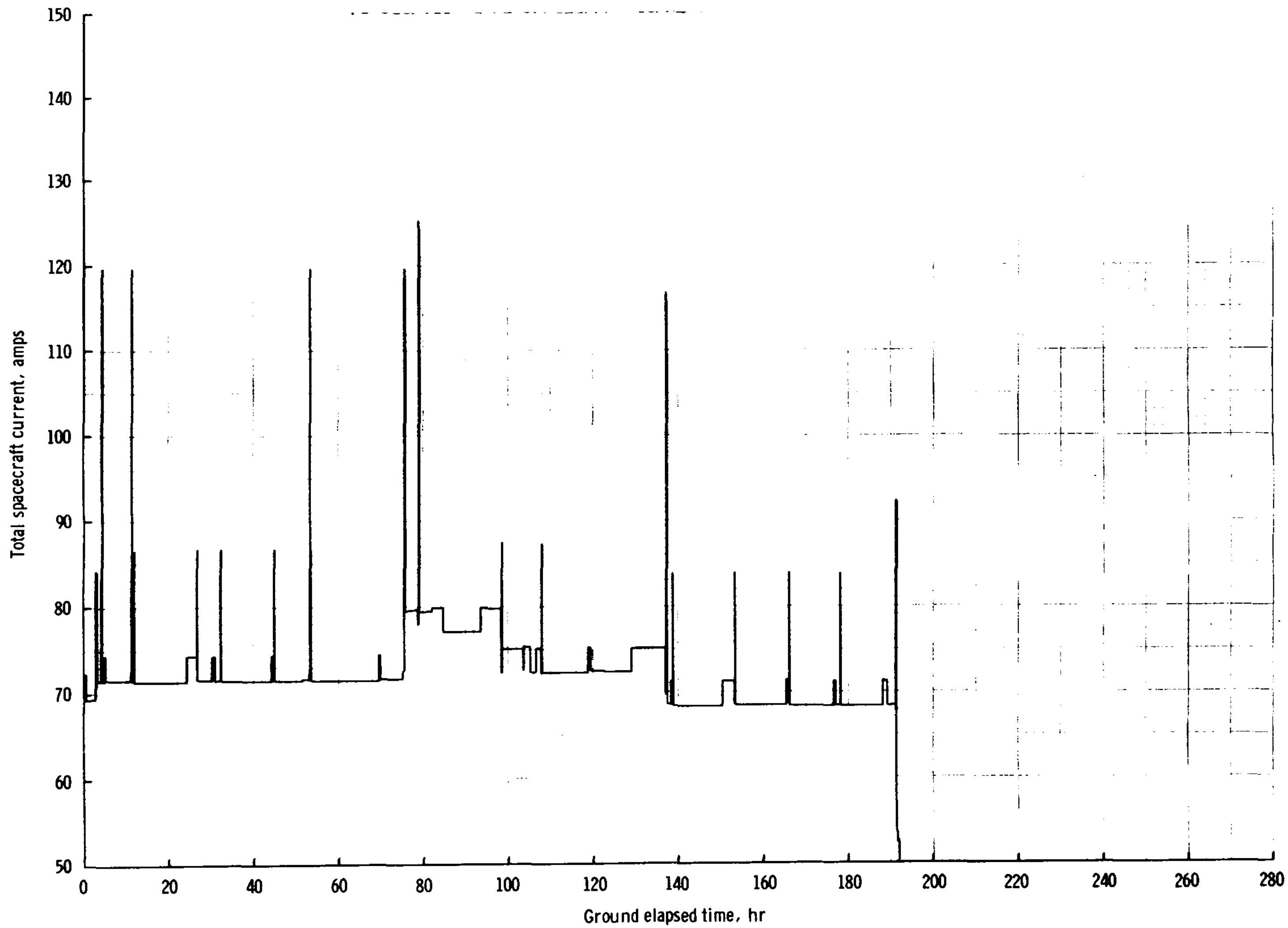


Figure 8-1. - Total CSM spacecraft current profile.

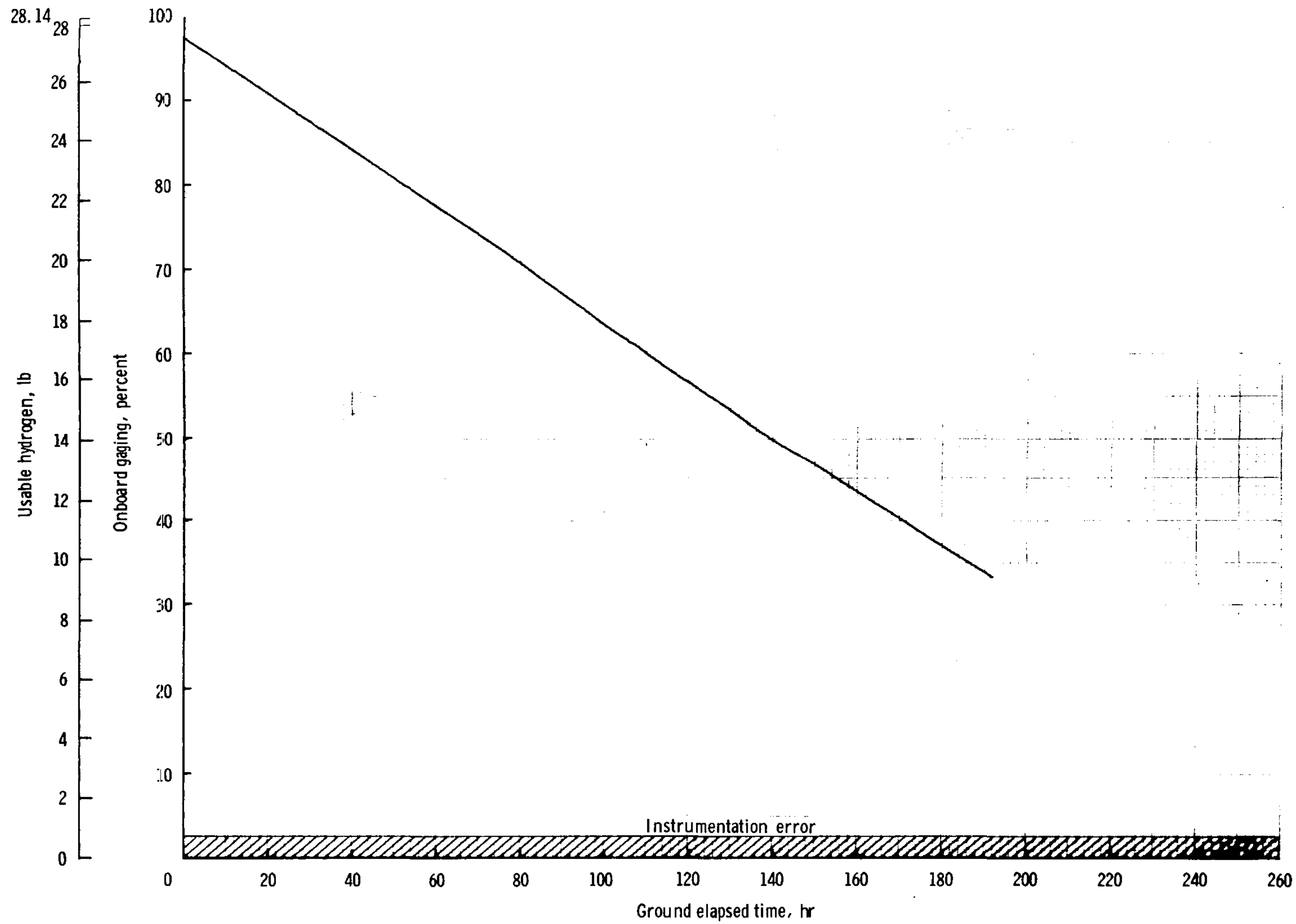


Figure 8-2. - Hydrogen remaining per tank, CSM.

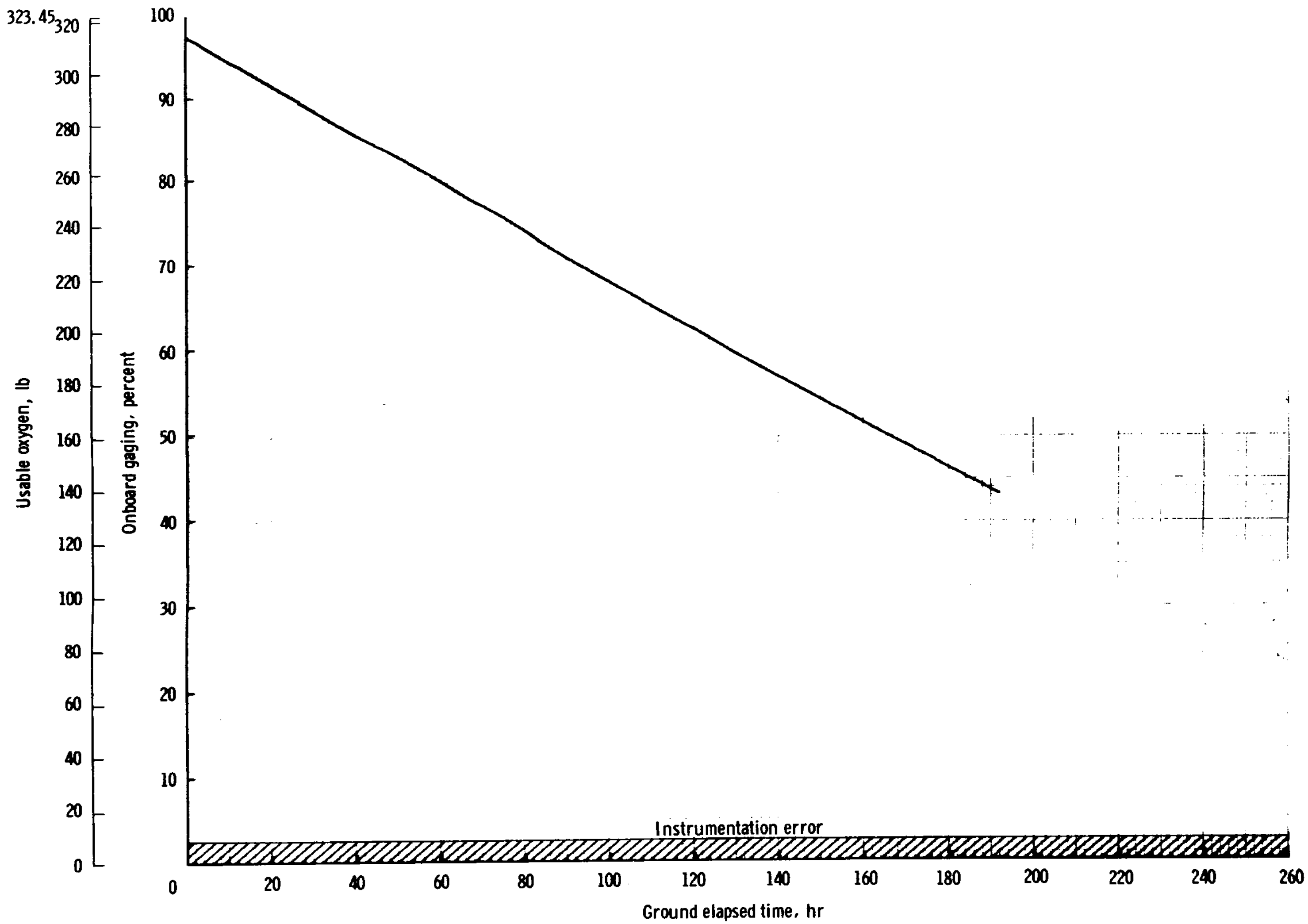


Figure 8-3.- Oxygen remaining per tank, CSM.

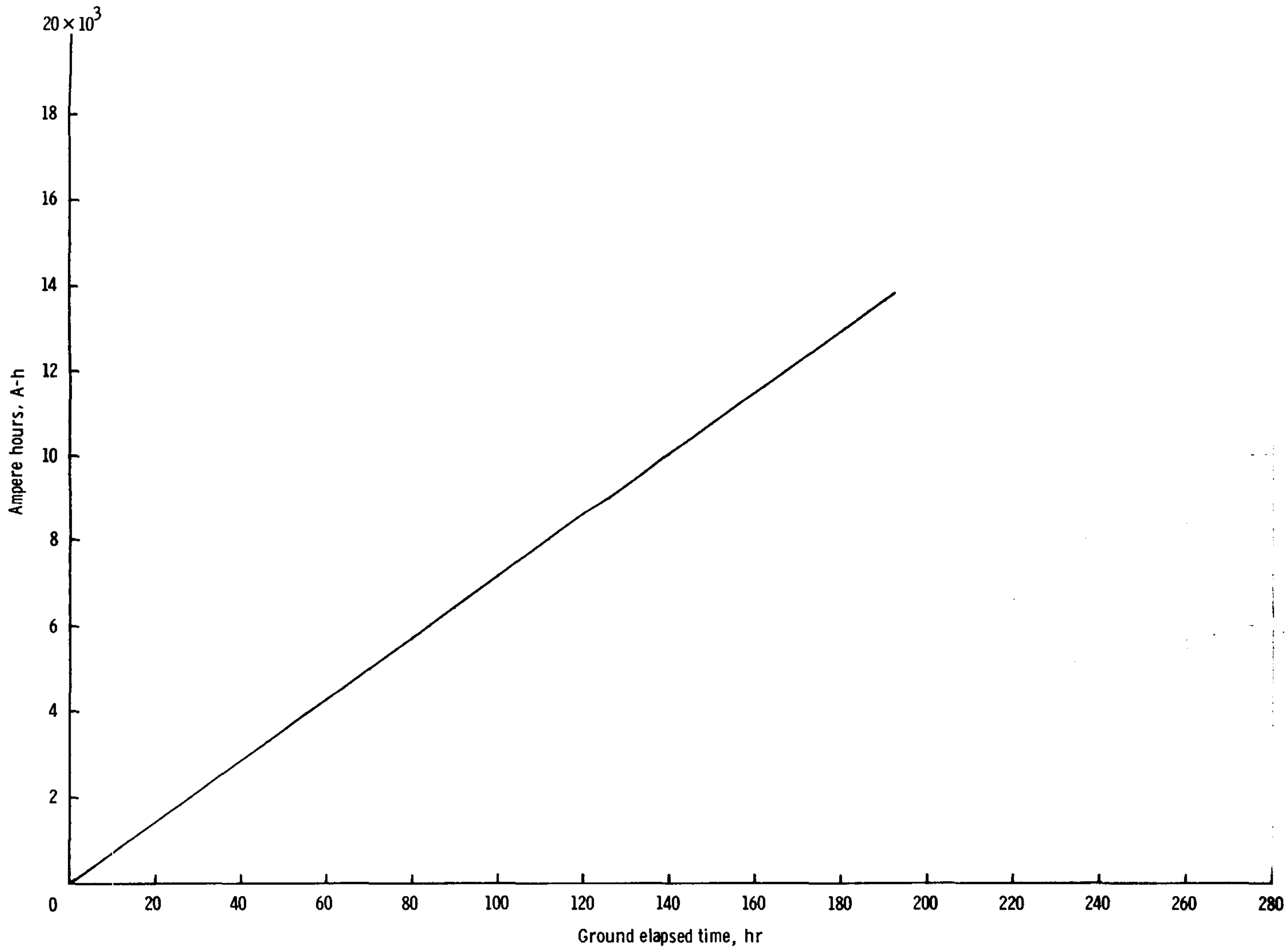


Figure 8-4. - Total DC energy.

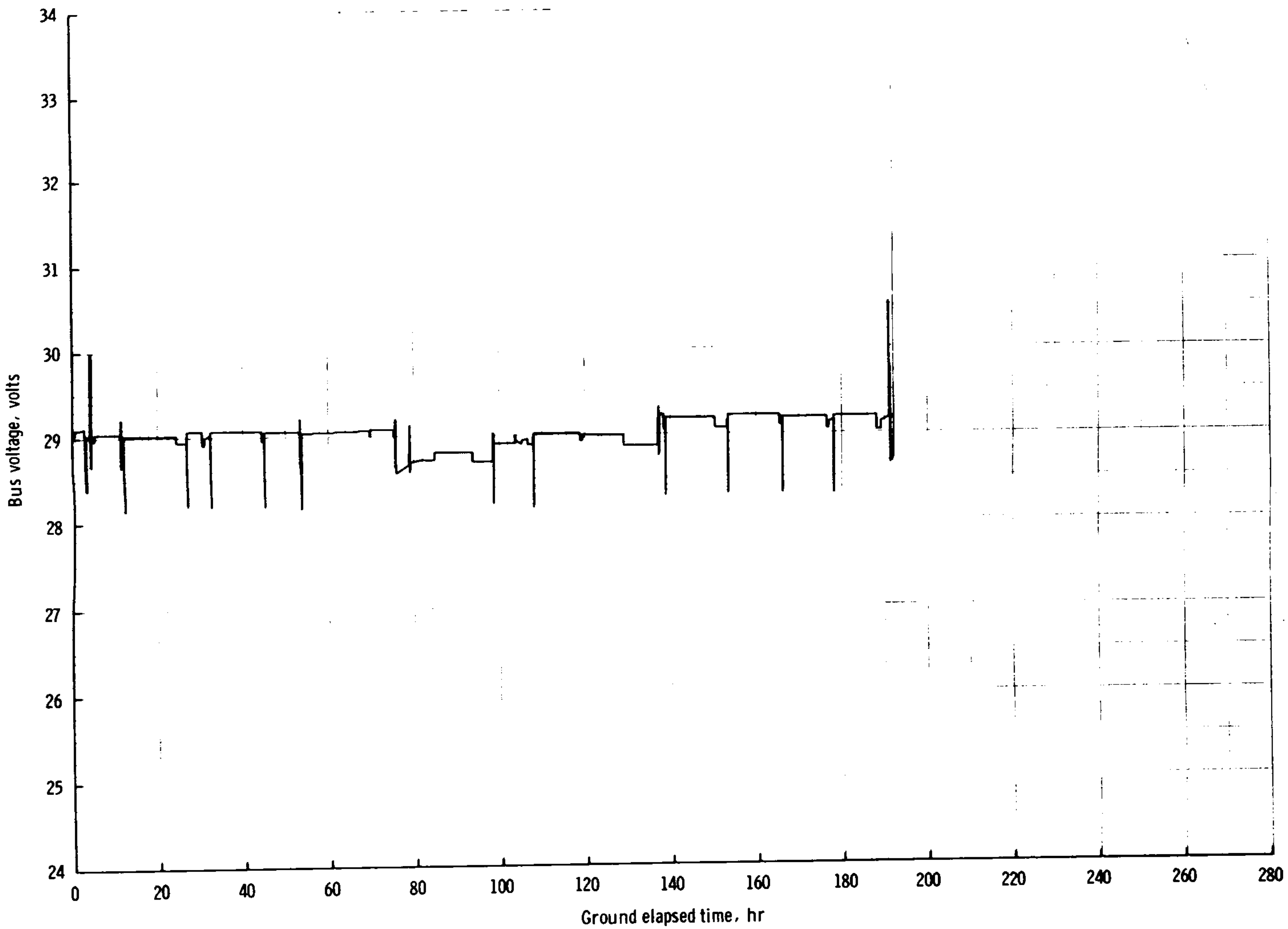


Figure 8-5. - CM bus voltage.

9.0 THE CSM ECS ANALYSIS

TABLE 9-I.- ASSUMPTIONS USED FOR THE ECS ANALYSIS

1. Average metabolic O_2 rate was as follows.

   a. One man, lb/hr. 0.066

   b. Two men, lb/hr. 0.131

   c. Three men, lb/hr. 0.197

2. Cabin leakage rate was 0.1 lb/hr.

3. Tunnel leakage rate was 0.05 lb/hr.

4. LM leakage rate was 0.1 lb/hr.

5. Waste management vent flows O_2 at 0.85 lb/hr.

6. H_2O tank bleed rate was 0.032 lb/hr.

7. Waste management was 0.024 lb/hr for the first 96 hours and was 0.051 lb/hr from 96 hours to end of mission.

8. Cabin temperature control was set at 70°F.

9. Water produced by the LIOH-CO_2 reaction was 0.108 lb/hr.

10. Crew water usage was 18.96 lb/day.

11. Water lost by crew micturition was 2.64 lb/day per man.

12. Waste tank water was dumped from 85% of full capacity to 25% of full capacity when the waste tank quantity reached 85% of full capacity.

13. Water tank capacities were the following.

    Potable, lb. 40

    Waste, lb. 60

14. Water tank quantities at lift-off were the following.

    Potable, lb. 21.2

    Waste, lb. 45.0

TABLE 9-I.- ASSUMPTIONS USED FOR THE ECS ANALYSIS - Continued

15. The water evaporator boiling efficiency was 100%.
16. The average glycol flow rate was approximately 225 lb/hr.
17. The heat loads of the cold-plated equipment were split so that 88% of the heat load went to the glycol, 9% was lost through the structure, and 3% went to the cabin.
18. The heat loads of the noncold-plated equipment were split so that 50% of the heat load went to the cabin and 50% was lost through the structure.

TABLE 9-II.- ECS OXYGEN REQUIREMENTS

Mission time, hr	Oxygen consumption rate, lb/hr	Δt, hr	Oxygen requirements, lb
0 - 3.2	1.203	3.2	3.85
3.2 - 4.5	.503	1.3	.65
4.5 - 8.0	1.353	3.5	4.73
8.0 - 95.92	.503	87.92	44.22
95.92 - 106.4	.215	10.48	2.25
106.4 - 107.7	.530	1.3	.69
107.7 - 192.0	.380	84.3	32.03
LM and tunnel pressurization at 3 hr 25 min			6.9
Tunnel pressurization at 106.4 hr			.3
Total ECS O_2 requirement, lb			95.62

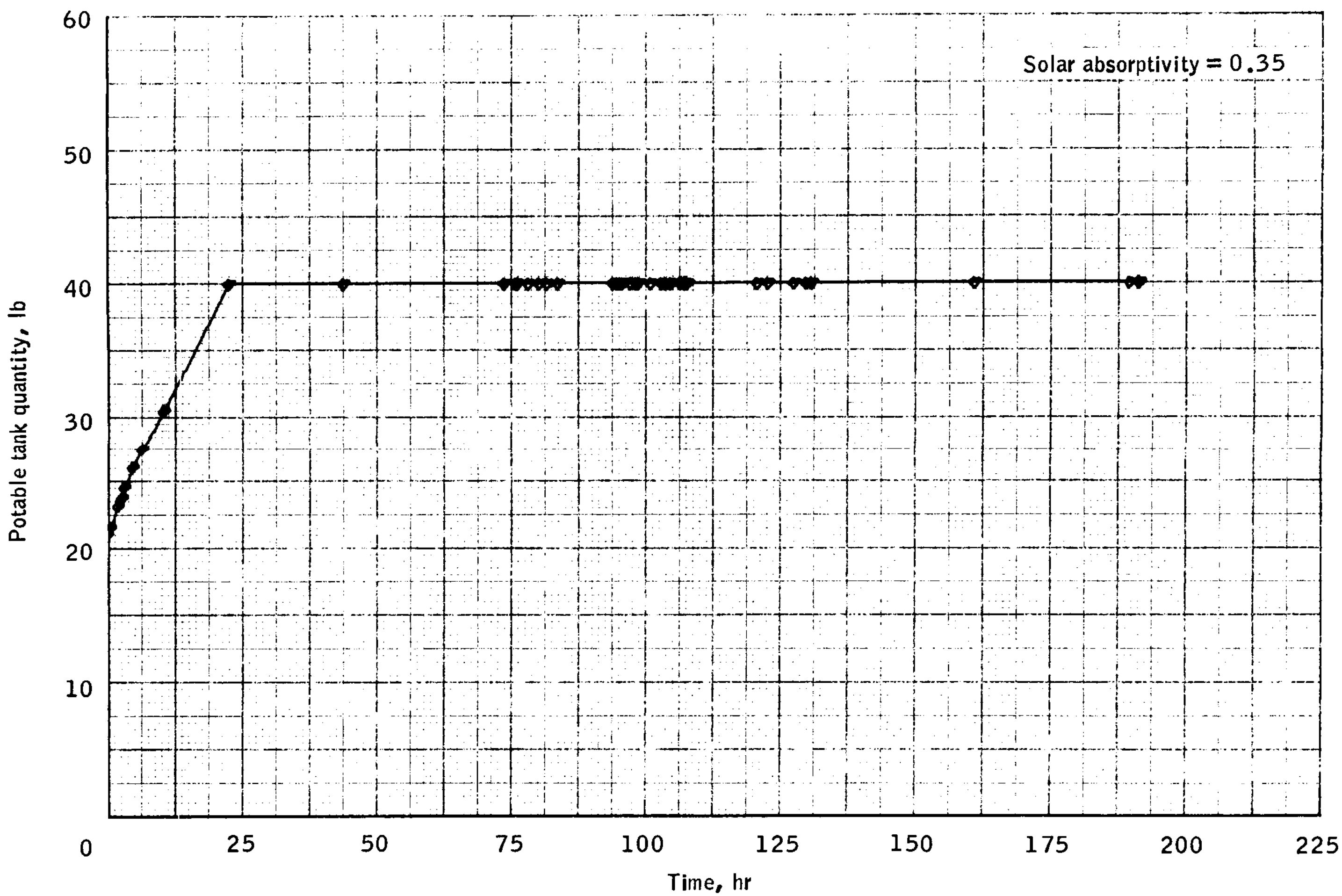


Figure 9-1.- Potable water tank quantities as a function of mission time.

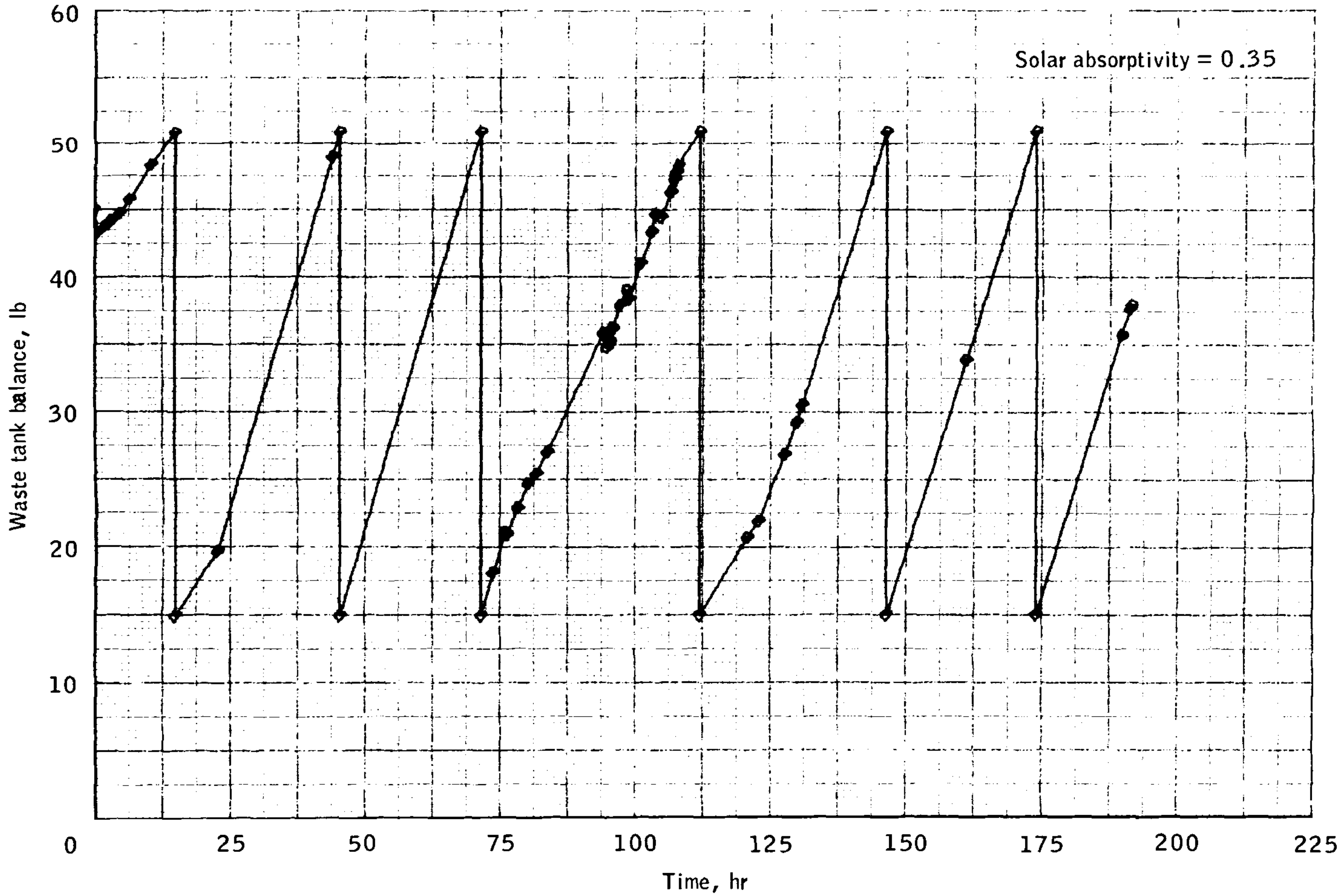


Figure 9-2.- Waste water tank quantities as a function of mission time.

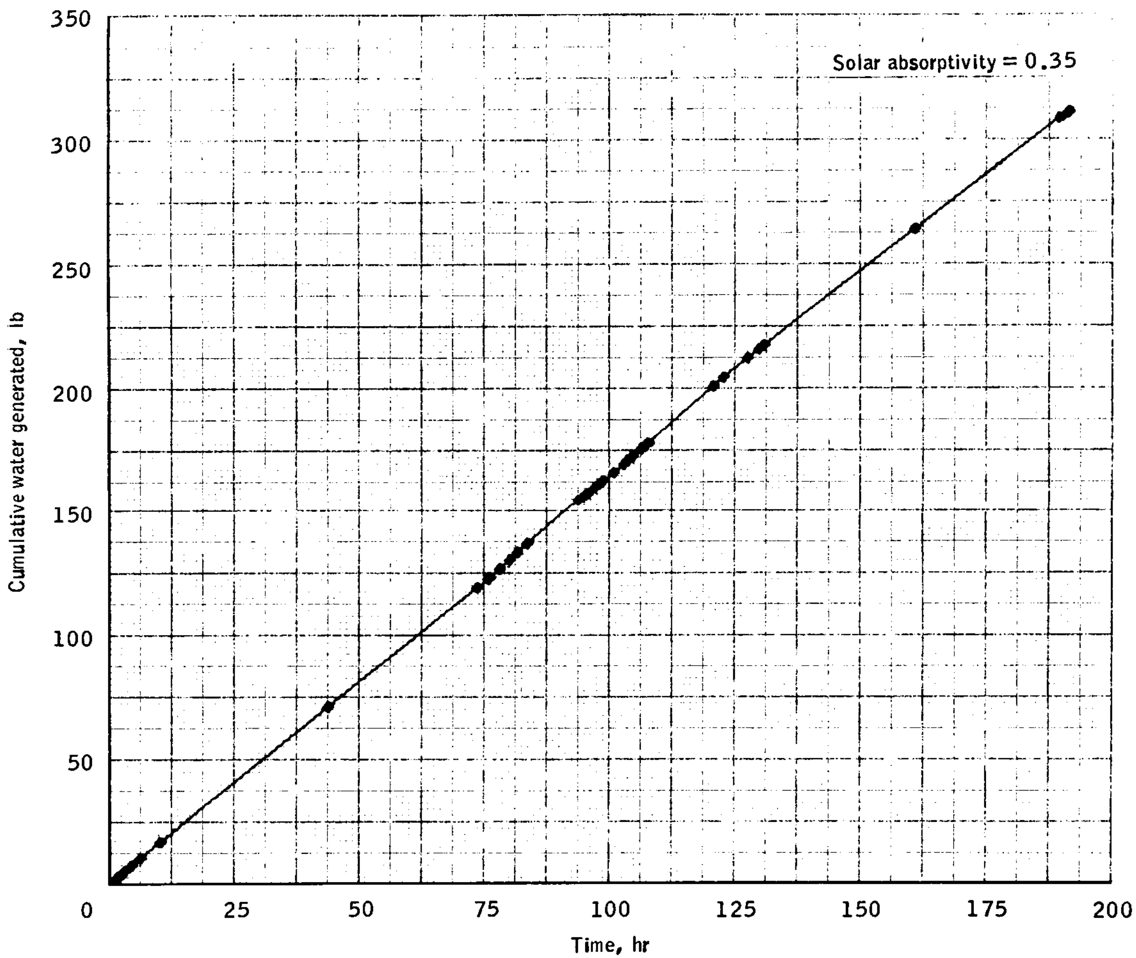


Figure 9-3.- CSM water generated as a function of mission time.

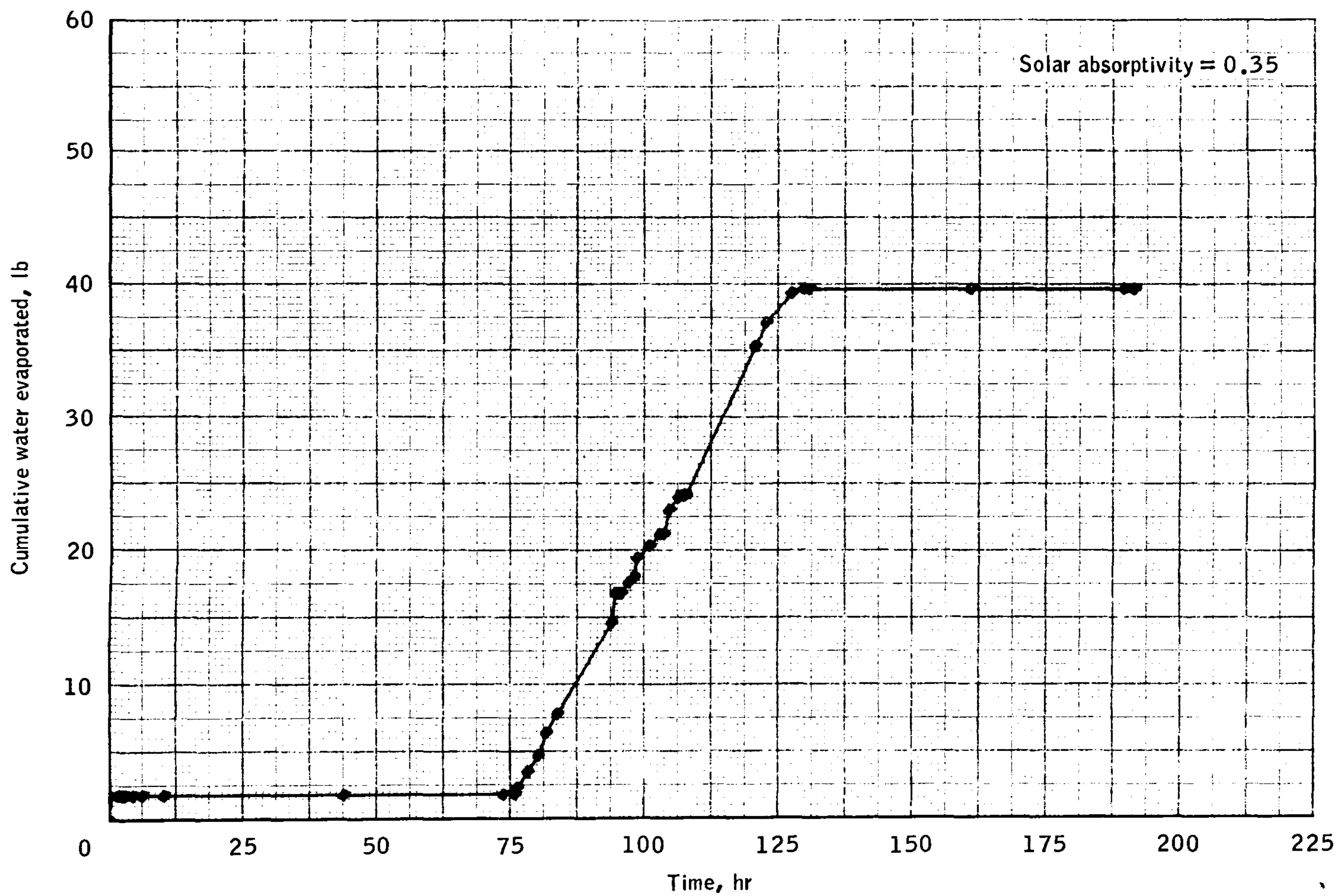


Figure 9-4.- CSM water evaporated for cooling as a function of mission time.

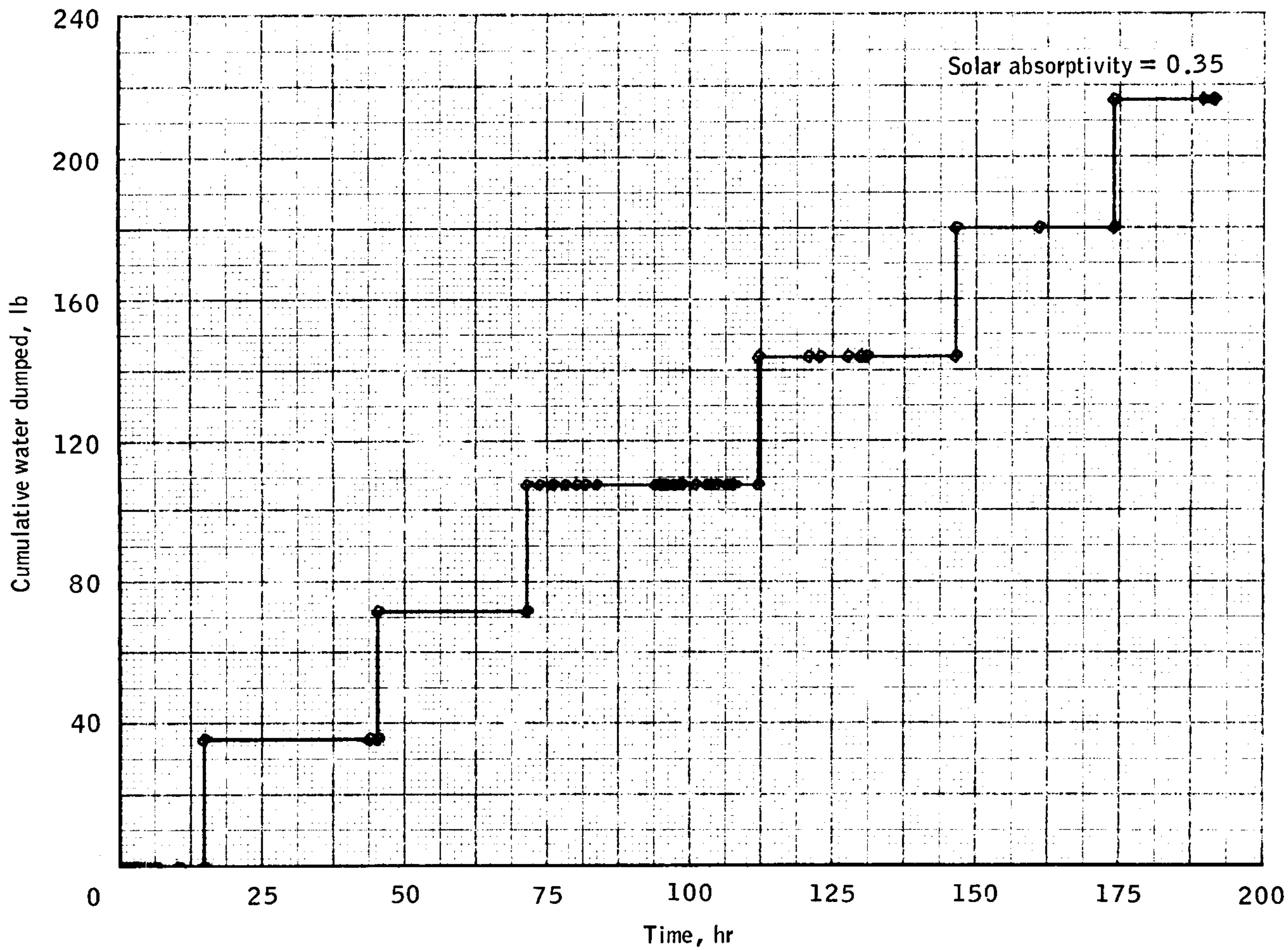


Figure 9-5.- CSM water dumped as a function of mission time.

10.0 THE LM EPS ANALYSIS

The LM descent and ascent stage battery energy used for the nominal mission is 423 A-h and 391 A-h, respectively. Unusables defined in assumptions 2, 3, and 4 of table 10-I indicate that the descent stage and ascent stage have 70 and 28 percent energy remaining, respectively.

TABLE 10-I.- ASSUMPTIONS FOR THE LM EPS ANALYSIS

1. Energy available for the descent stage batteries is 1600 A-h and for the ascent stage batteries is 592 A-h.
2. Energy unusable for the descent stage batteries and the ascent stage batteries because of lack of MSFN coverage is 21 A-h and 7 A-h, respectively.
3. Energy unusable for the descent stage batteries and the ascent stage batteries because of telemetry inaccuracy is 14 A-h and 11 A-h, respectively.
4. Energy unusable for the descent stage batteries and the ascent stage batteries because of equipment power dispersions is 21 A-h and 20 A-h, respectively.
5. The descent stage batteries would go on the line at lift-off minus 30 minutes with no recycle on the pad. They would go off the line again at transposition and docking.

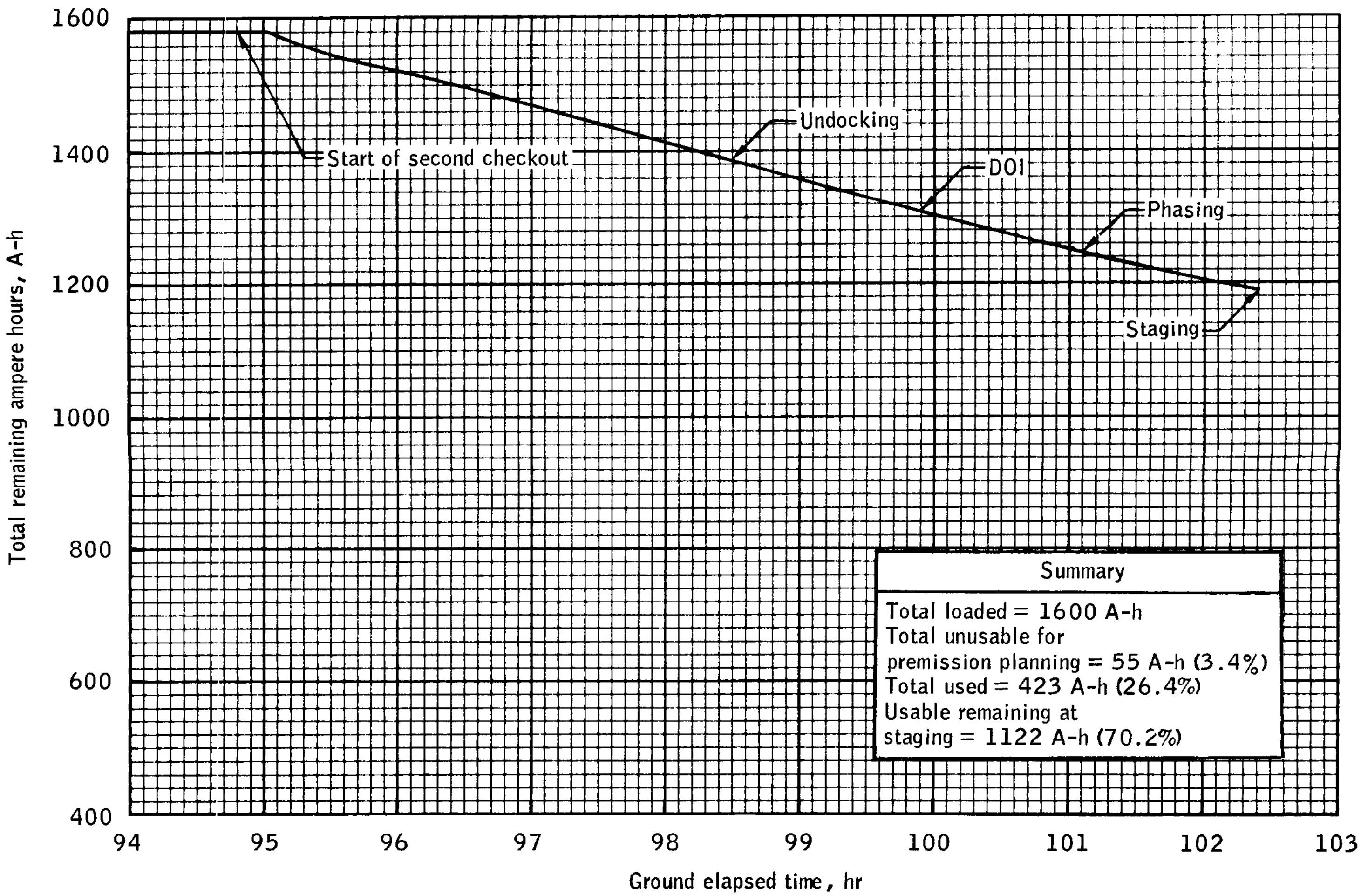


Figure 10-1.- Apollo 10 descent stage electrical power profile.

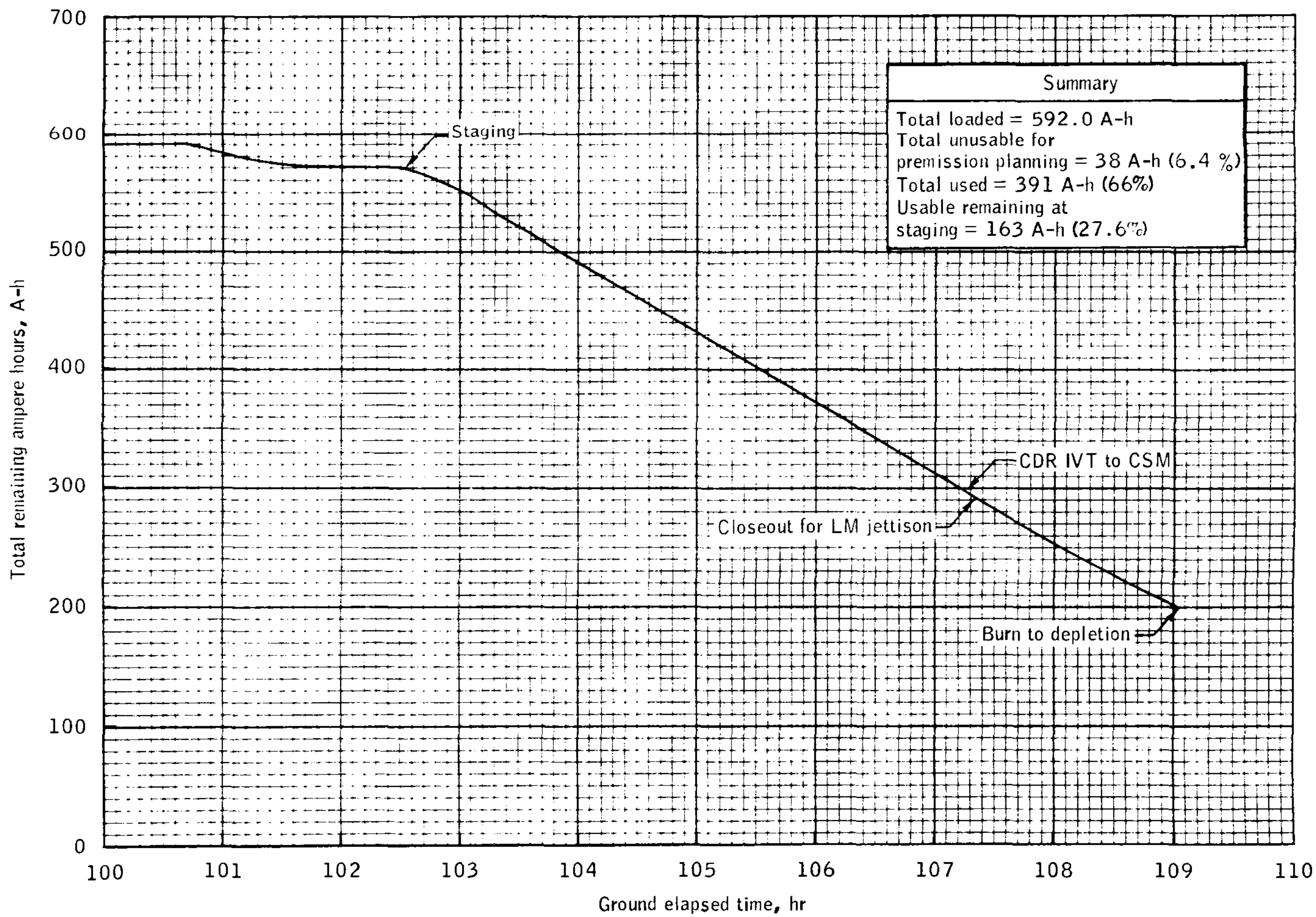


Figure 10-2.- Apollo 10 ascent stage electrical power profile.

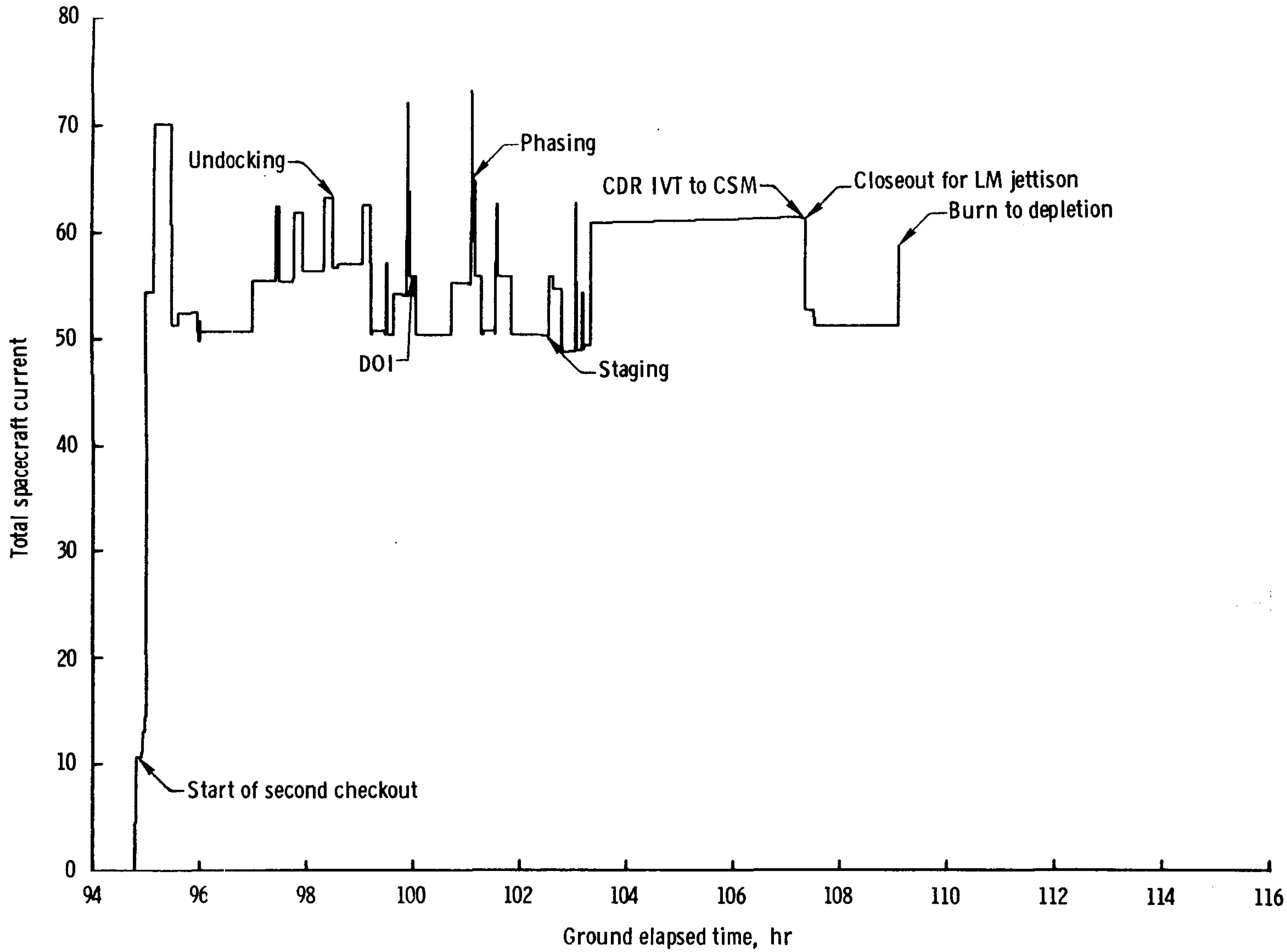


Figure 10-3. - LM-4 total spacecraft current.

11.0 THE LM ECS ANALYSIS

Because of the late availability of a revised trajectory and updated EPS data, the ECS analysis shown in this report is based on a previous flight plan and trajectory. A revised ECS analysis will be performed and documented as soon as the above information is available. However, this analysis is presented here because it provides a good estimate of the ECS requirements.

TABLE 11-I.- ASSUMPTIONS FOR THE LM ECS ANALYSIS

1. Cabin O_2 leakage rate was 0.1 lb/hr while pressurized.

2. Metabolic rates were varied according to reference 2.

3. Metabolic O_2 consumed was $(1.643 \times 10^{-4}) \times$ (metabolic rate).

4. H_2O consumed because of sublimator cooling was (total heat load, Btu/hr) $\times$ ($H_2O \times 1/1040$, Btu/lb).

5. H_2O lost because of micturition was 0.11 lb/hr/man.

6. Cabin temperature control was set at 75° F.

7. Average glycol flow rate was 250 lb/hr.

8. Uncertainty in the water profile was calculated using 1 lb/hr.

9. Uncertainty in the oxygen profile was calculated as 5% of the required O_2 plus 0.1 lb/hr for the uncertainty in the cabin leakage rate.

TABLE 11-II.- LM ECS CONSUMABLES SUMMARY

(a) Descent stage		
Description	O_2, lb	H_2O, lb
Loaded	48.00	333.00
Unusable	3.40	26.00
Available for mission	44.60	307.00
Required for mission	3.57	63.75
Usable remaining in tanks	41.03	264.25
(b) Ascent stage		
Loaded	4.86	85.00
Unusable	.74	4.20
Available for mission	4.12	80.80
Required for mission	1.27	47.67
Usable remaining in tanks	2.85	33.13

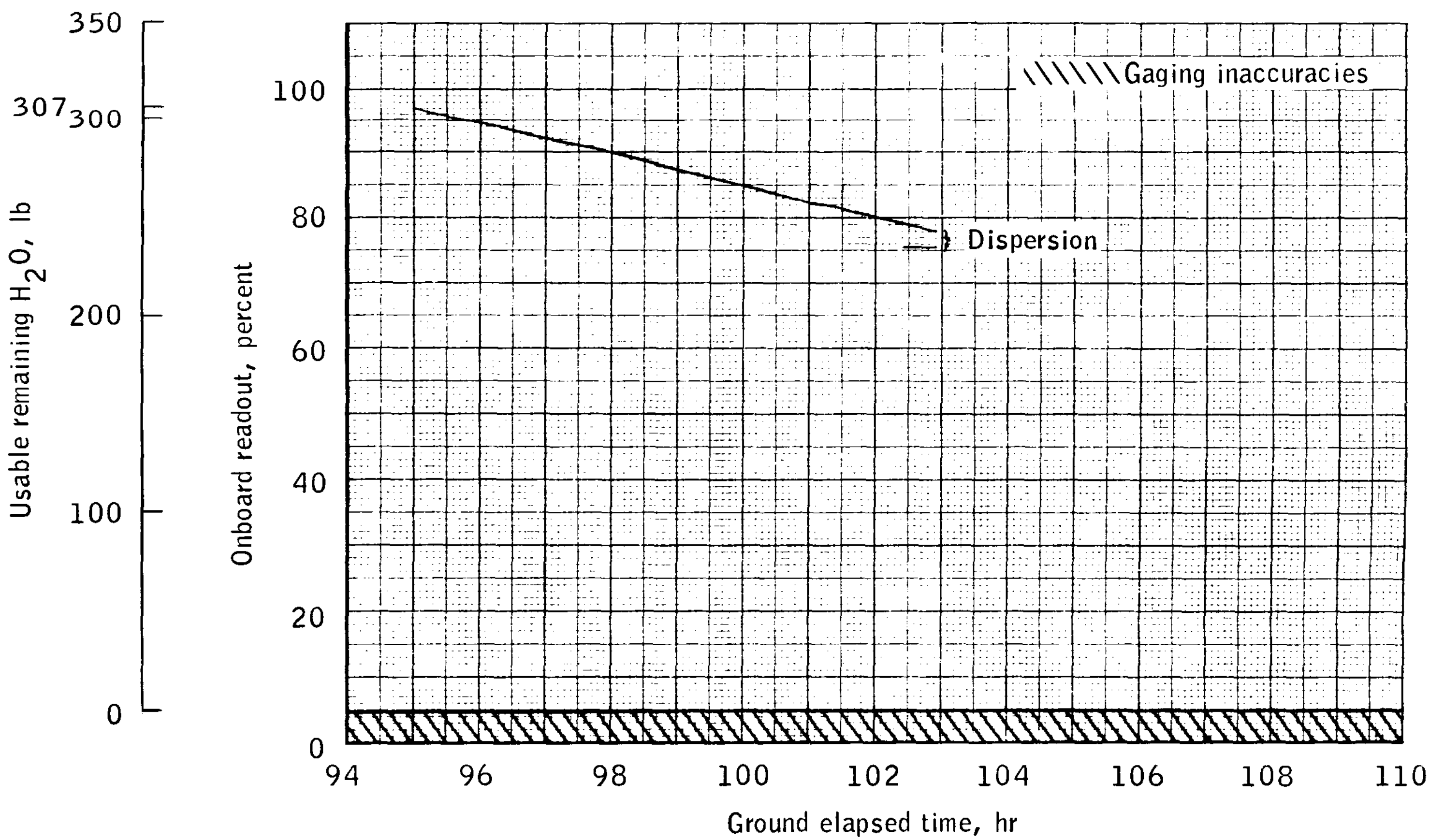


Figure 11-1.-Descent stage water tank quantities as a function of mission time.

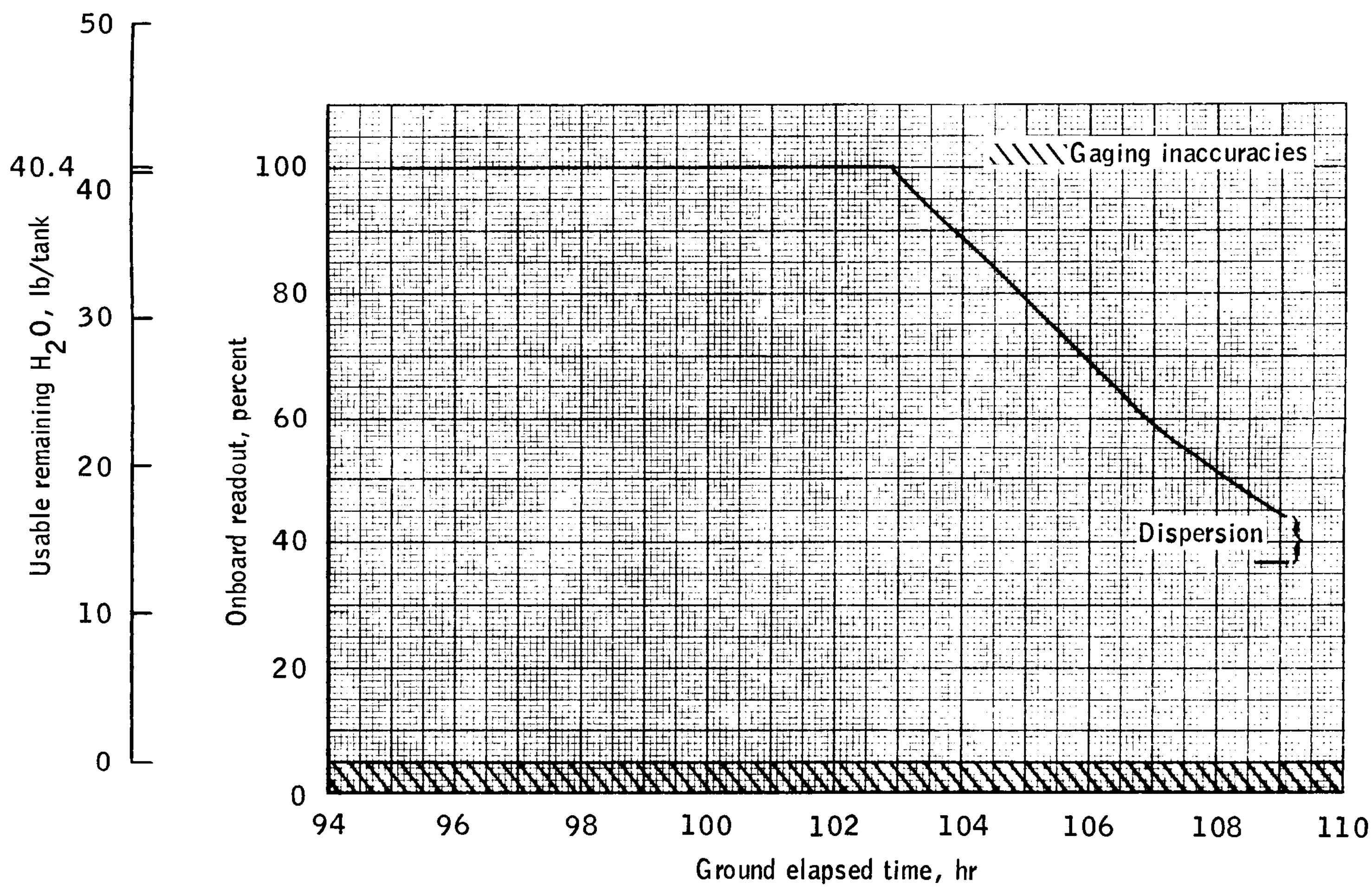


Figure 11-2.- Ascent stage water tank quantities as a function of mission time.

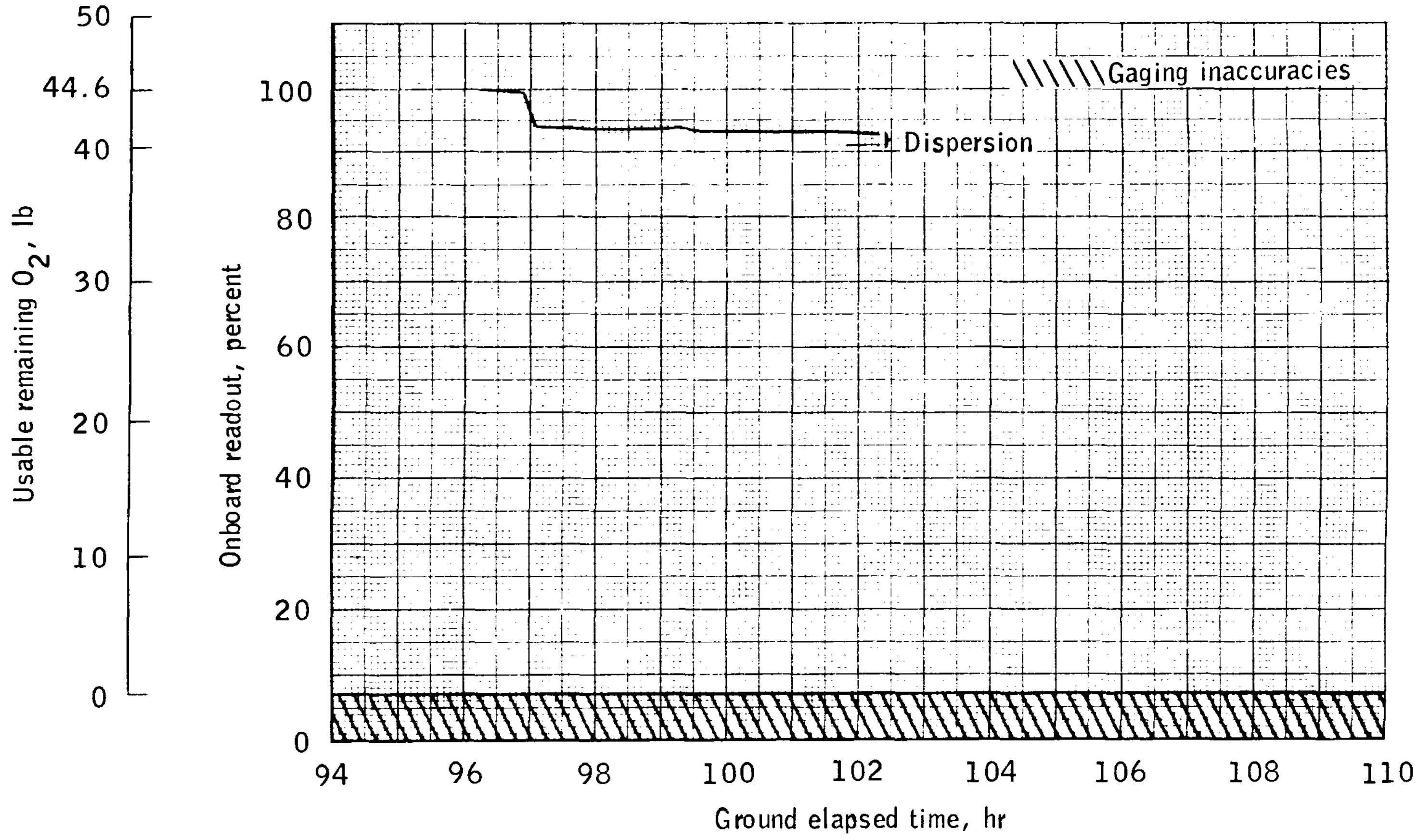


Figure 11-3.-Descent stage oxygen tank quantities as a function of mission time.

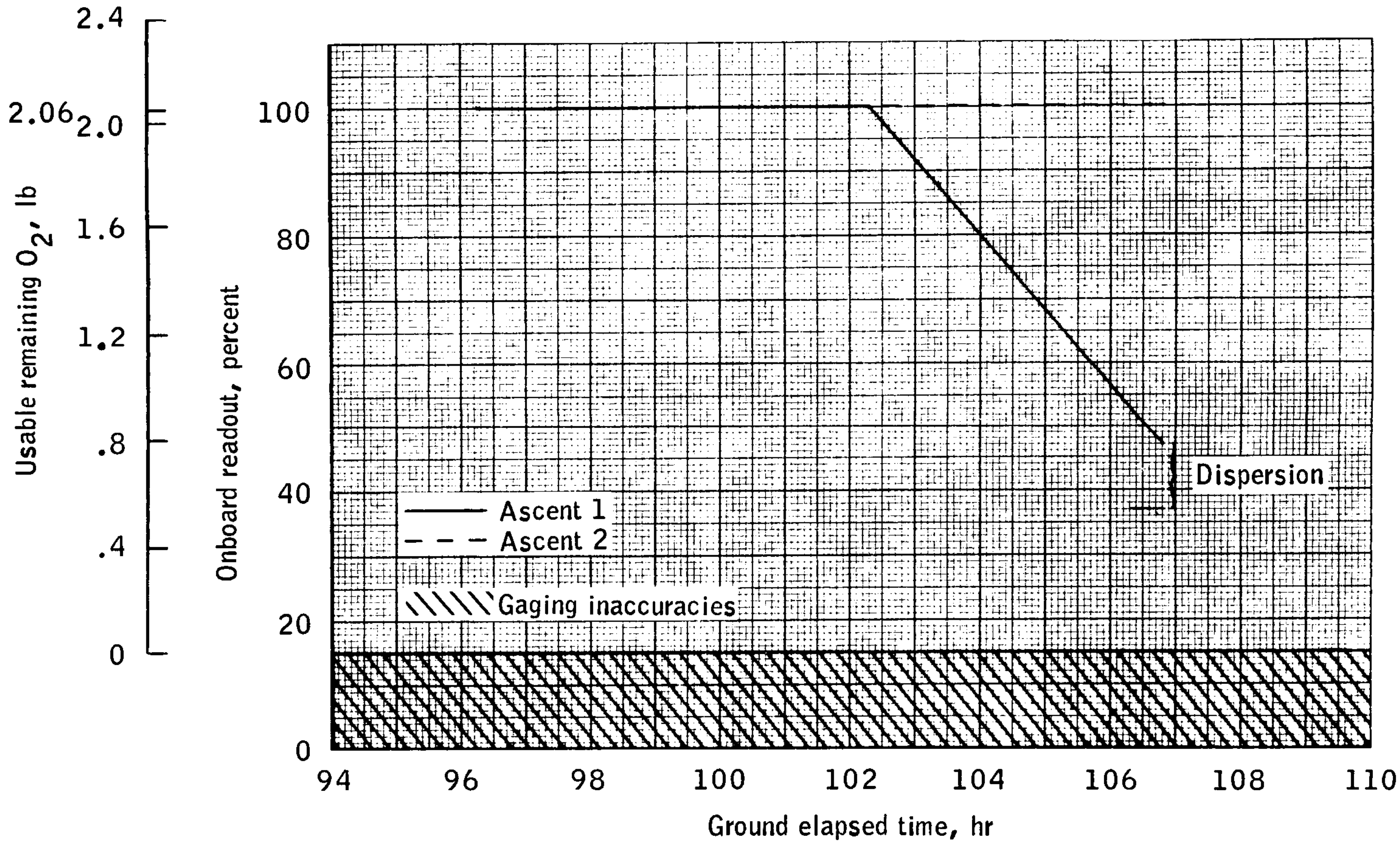


Figure 11-4.-Ascent stage oxygen tank quantites as a function of mission time.

TABLE [illegible]-I.- TIME HISTORY OF CONSUMABLES WEIGHT LOSS

Mission time, hr	Event	H_2O weight loss, lb		RCS weight loss, lb		APS weight loss, lb	DPS weight loss, lb	SPS weight loss, lb
		CSM	LM	CSM	LM			
3:20	Lift-off to extraction	12	--	107.6	--	--	--	--
11:33	Extraction to MCC-1	5	--	45.2	--	--	--	1139.7
26:30	MCC-1 to MCC-2	39	--	53.4	--	--	--	--
53:45	MCC-2 to MCC-3	42	--	66.0	--	--	--	--
70:45	MCC-3 to MCC-4	4	--	30.9	--	--	--	--
75:48	MCC-4 to LOI-1	37	--	17.9	--	--	--	23 650.8
80:10	LOI-1 to LOI-2	4	--	32.6	--	--	--	[illegible].9
98:35	LOI-2 to CSM/LM SEP	17	--	109.9	5	--	--	--
99:34	SEP to DOI	--	10	↑	36.0	--	308.2	--
100:46	DOI to LM phasing	--	8	│	28.4	--	767.8	--
102:33	LM phasing to staging	--	16	127.6	40.0	--	--	--
102:43	Staging to LM insertion	--	--	│	6.8	174.8	--	--
103:34	Insertion to CSI	--	8	│	32.1	32.3	--	--
104:32	CSI to CDH	--	8	│	30.6	--	--	--
105:09	CDH to TPI	--	6	│	34.4	--	--	--
106:20	TPI to Docking	8	8	↓	104.9	--	--	--
10[illegible]:09	Docking to LM jettison	2	14	[illegible].4	--	--	--	--
108:39	APS burn to depletion	--	--	--	--	2375.7	--	--
137:20	LM jettison to TEI	56	--	97.8	--	--	--	11 101.4
152:20	TEI to MCC-5	36	--	33.8	--	--	--	--
176:50	MCC-5 to MCC-6	37	--	57.8	--	--	--	--
188:50	MCC-6 to MCC-7	1	--	17.2	--	--	--	--
191:35	MCC-7 to CM/SM SEP	--	--	14.1	--	--	--	--

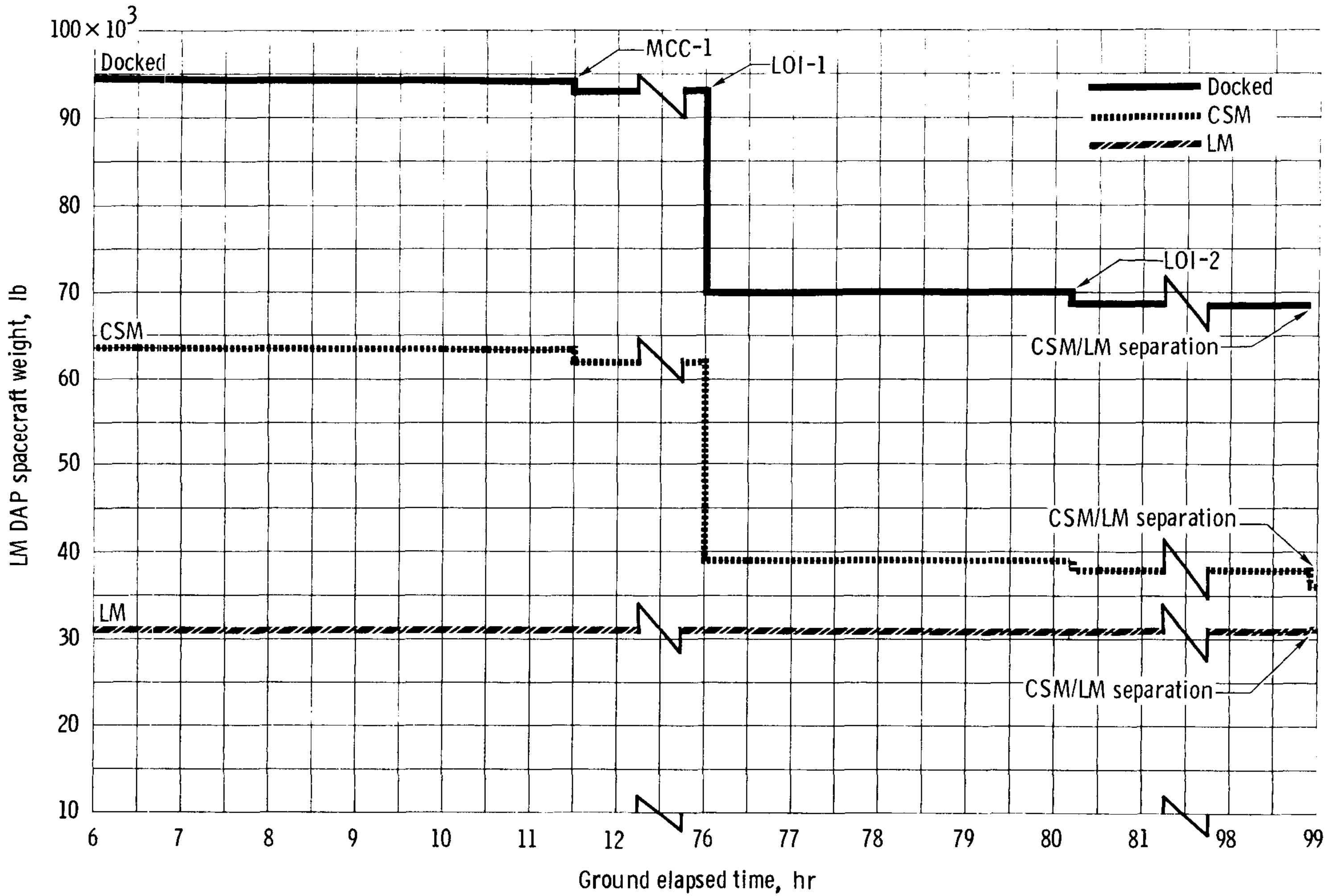


Figure 12.1. - Spacecraft weight versus ground elapsed time.

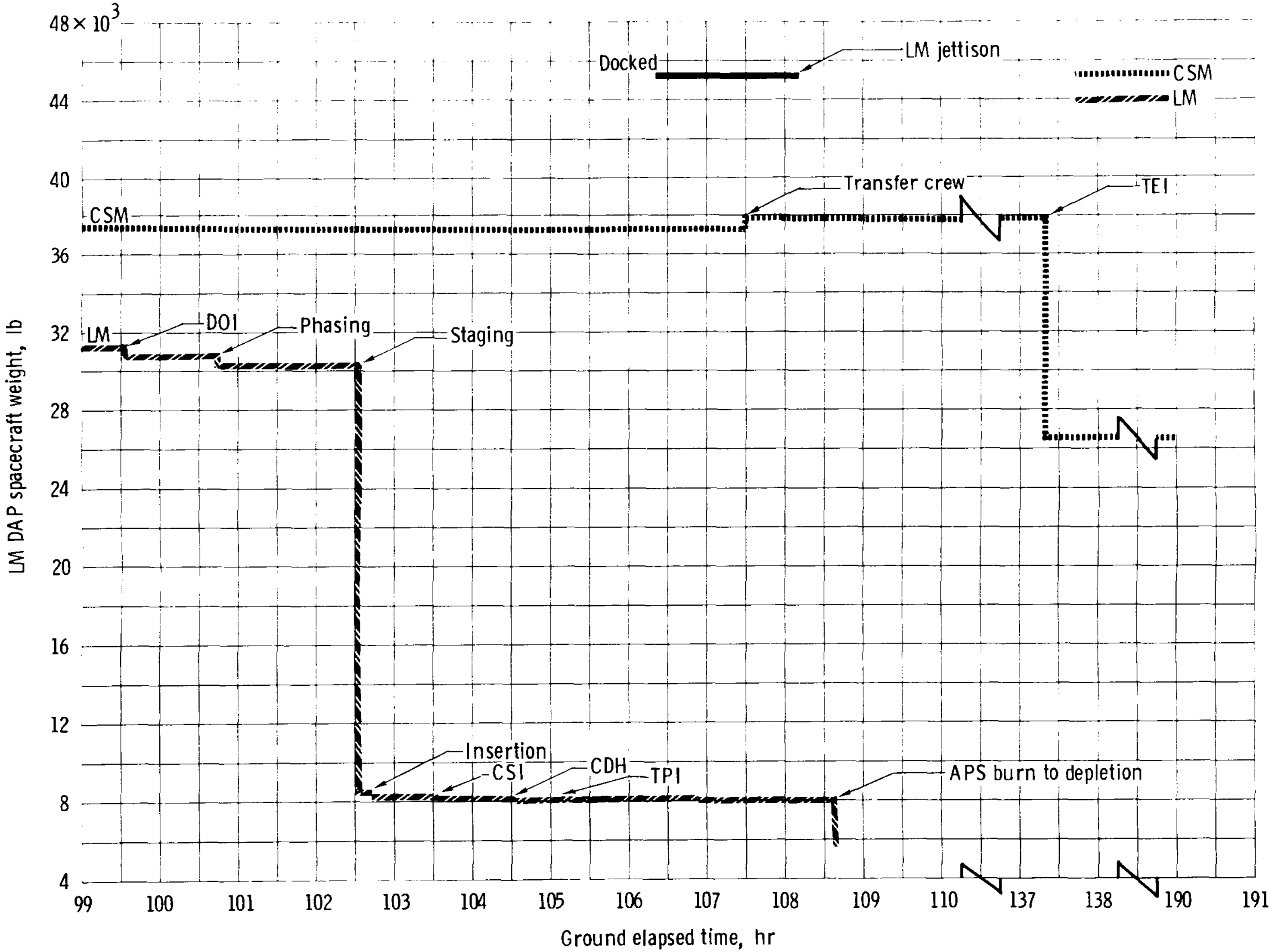


Figure 12.1.- Concluded.

13.0 REFERENCES

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