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May 9, 1969

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

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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

May 9, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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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<br>NON PROPULSIVE | 63529. | .0 | 1220.0 | 100. |
| 3.1 | TRANSPOSITION AND DOCKING<br>+X .8FPS, NULL TO 0.3 FPS | 63517. | 12.2 | 1207.8 | 99. |
| 3.1 | PITCH TO ACQUIRE SIVB<br>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 FAMILIARIZAT<br>IONINCREASED PER APOLLO 9 RESULTS | 63455. | 49.3 | 1146.3 | 94. |
| 3.2 | INDEX AND DOCK<br>LANGLEY STUDY | 63429. | 26.0 | 1120.3 | 92. |
| 4.1 | LM EJECTION PLUS RCS BURN<br>4 JETS, 5 SEC | 94267. | 7.9 | 1112.4 | 91. |
| 4.5 | SPS BURN TO EVADE SIVB<br>3 AXIS ORIENT PGNCS | 94263. | 4.1 | 1108.3 | 91. |
| 4.5 | ATTITUDE HOLD | 94263. | .4 | 1107.9 | 91. |
| 4.5 | SPS BURN<br>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<br>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<br>MNVR TO BURN ATT | 93965. | 4.1 | 966.6 | 79. |
| 53.7 | ATTITUDE HOLD | 93964. | .7 | 966.0 | 79. |
| 53.7 | SPS BURN<br>BUILD UP | 93961. | .0 | 966.0 | 79. |
| 53.7 | STEADY STATE BURN | 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<br>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<br>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<br>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 ATTITUDE | 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 ON 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<br>ROLL 180 DEG | 37934. | .5 | 497.5 | 41. |
| 136.3 | - ATTITUDE HOLD | 37934. | .4 | 497.1 | 41. |
| 136.3 | ULLAGE<br>2 JETS B AND D | 37918. | 15.2 | 481.9 | 39. |
| 137.3 | SPS BURN<br>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 SETS | 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. |

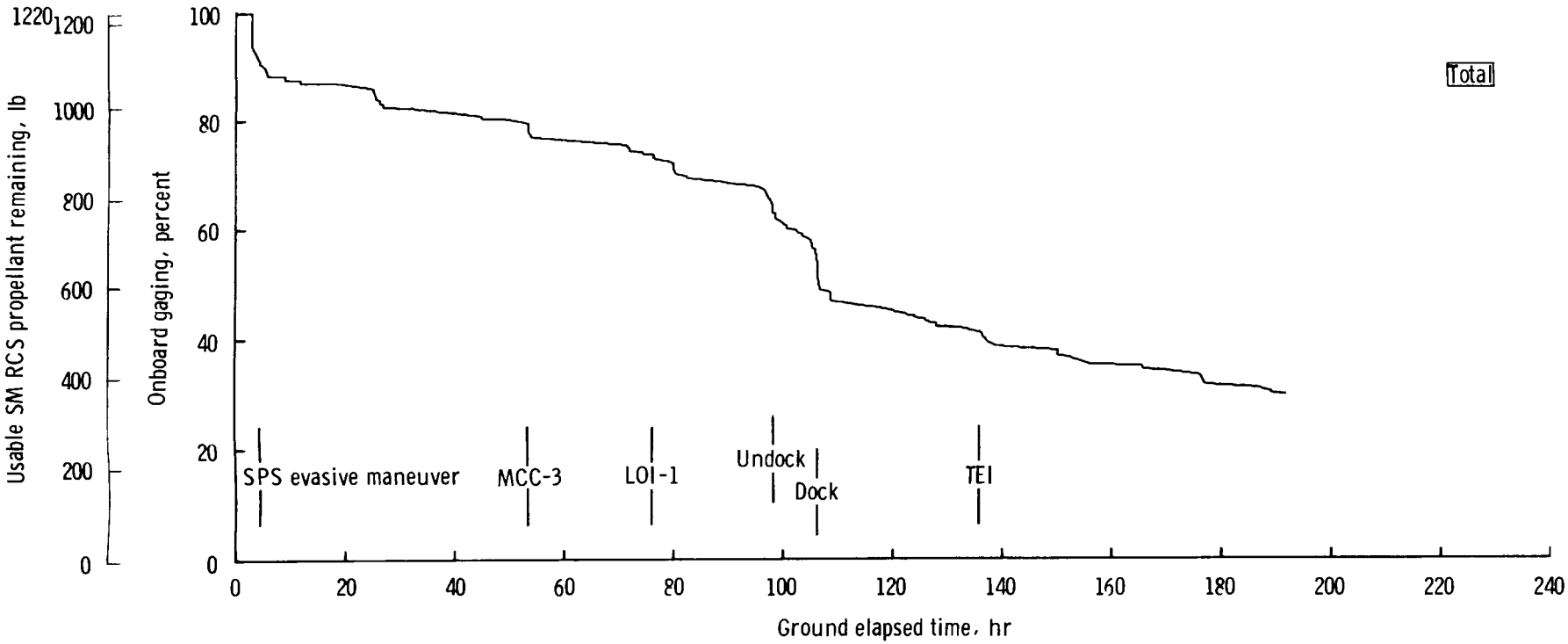
TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

| 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<br>STAR/LUNAR HORIZON ORIENT | 28653. | 5.9 | 423.4 | 35. |
| 165.5 | ORIENT FOR PTC<br>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<br>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<br>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

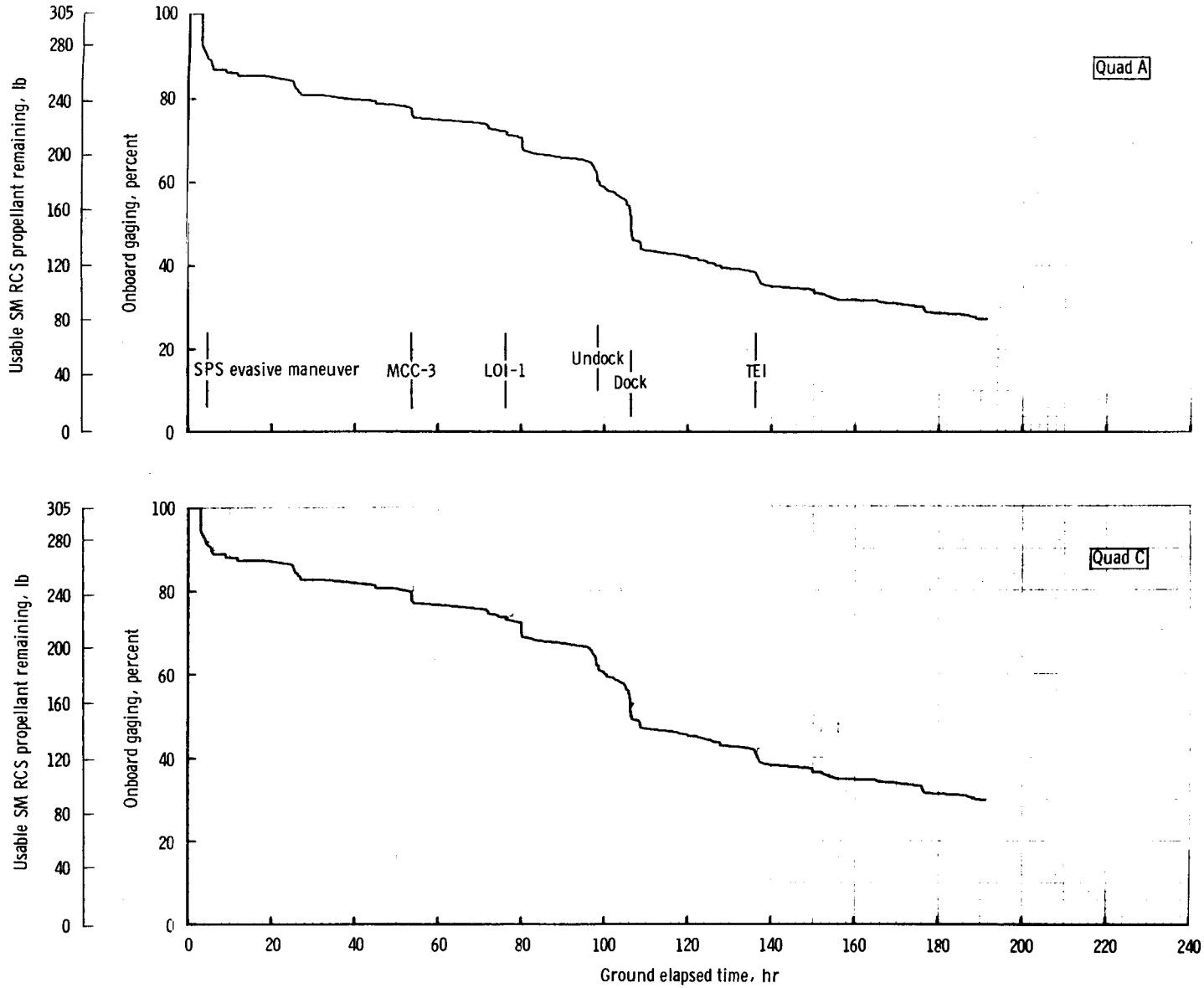
| TIME (HR) | EVENT | S/C WT (LBS) | SM-RCS USED (LBS) | SM-RCS LEFT (LBS) | SM-RCS LEFT (%) |
|---|---|---|---|---|---|
| 176.7 | ORIENT FOR PTC<br>3AXIS 0.2 DEG/SEC | 28618. | .6 | 388.9 | 32. |
| 176.7 | ESTABLISH ROLL | 28618. | .2 | 388.7 | 32. |
| 176.7 | PITCH AND YAW CONTROL | 28609. | 9.0 | 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<br>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<br>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.



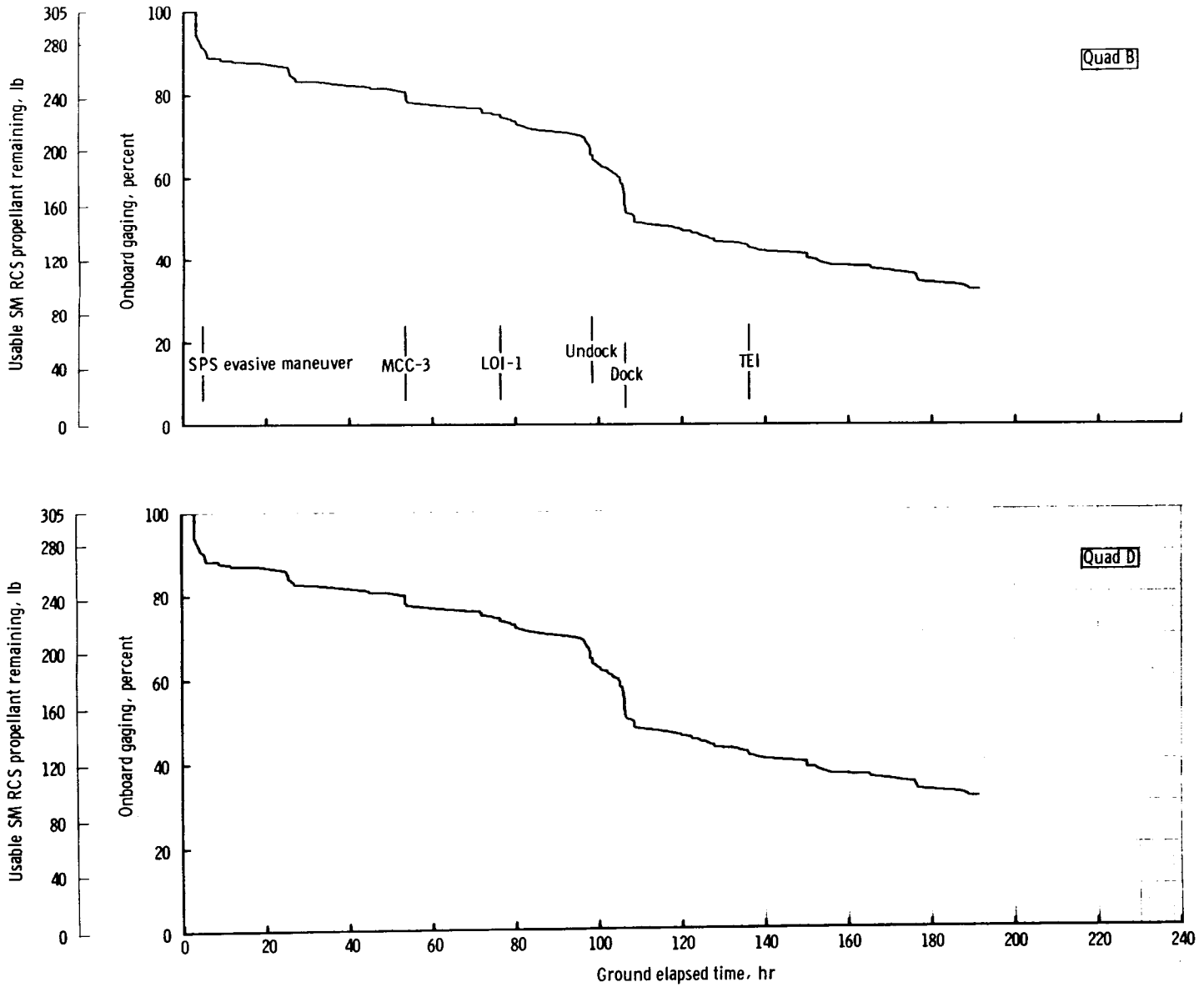

(a) Total.

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 $\Delta V$ required from the SPS (320.5 fps) is well within the 900 fps mission flexibility $\Delta V$ 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 $\Delta V$ requirements are taken from reference 9.

Note that the mission flexibility $\Delta V$ 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 $\Delta V$.

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 $\Delta V$ | -- | 40 188.8 |
| Required for $\Delta V$ | | |
| 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 $\Delta V$ (900 fps) | 2234.1 | 1 109.9 |
| Dispersions ($-3\sigma$) | 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. |

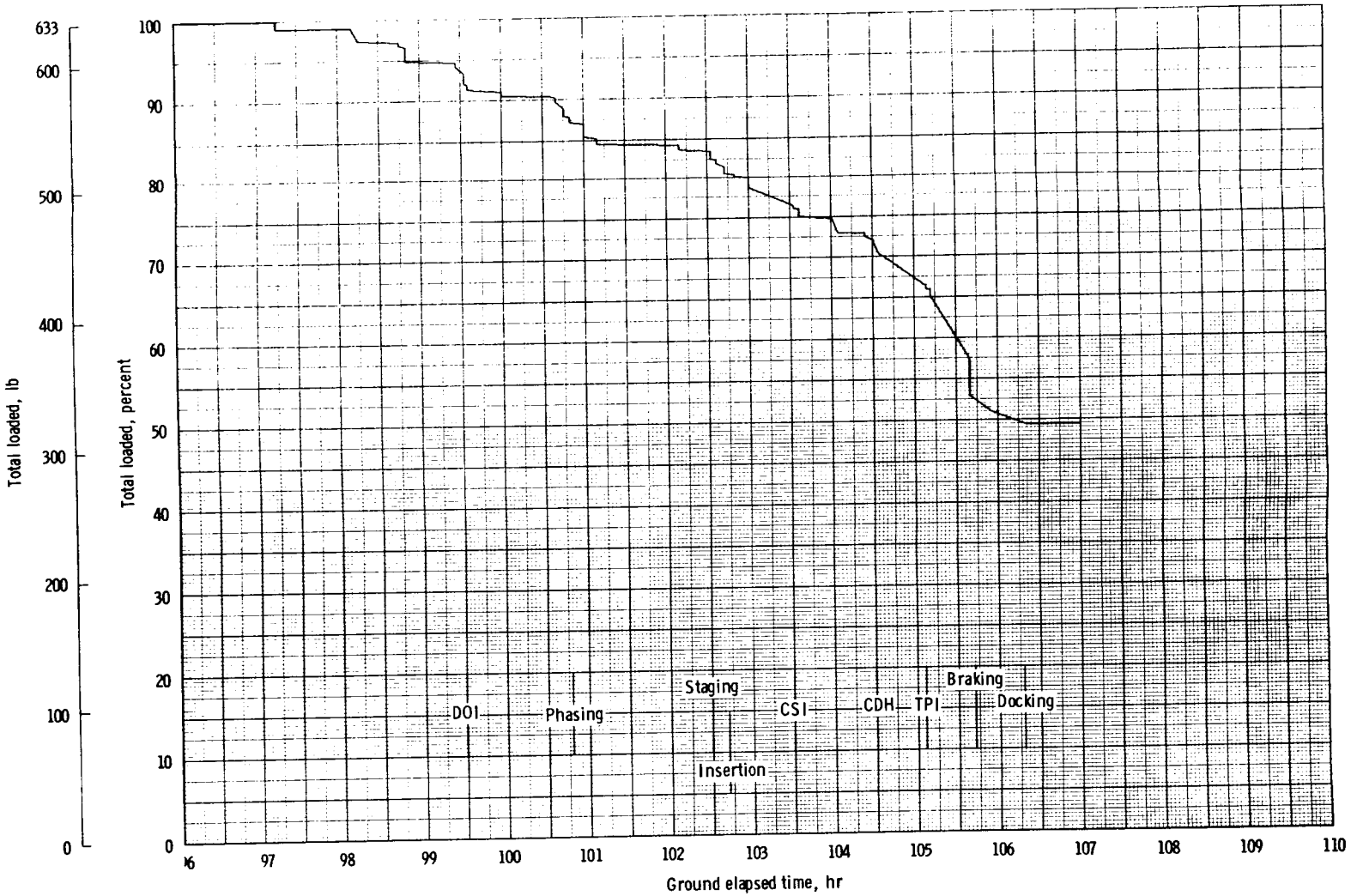



Figure 5-1. - LM RCS propellant profile.

## 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 $\Delta V$ 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 |

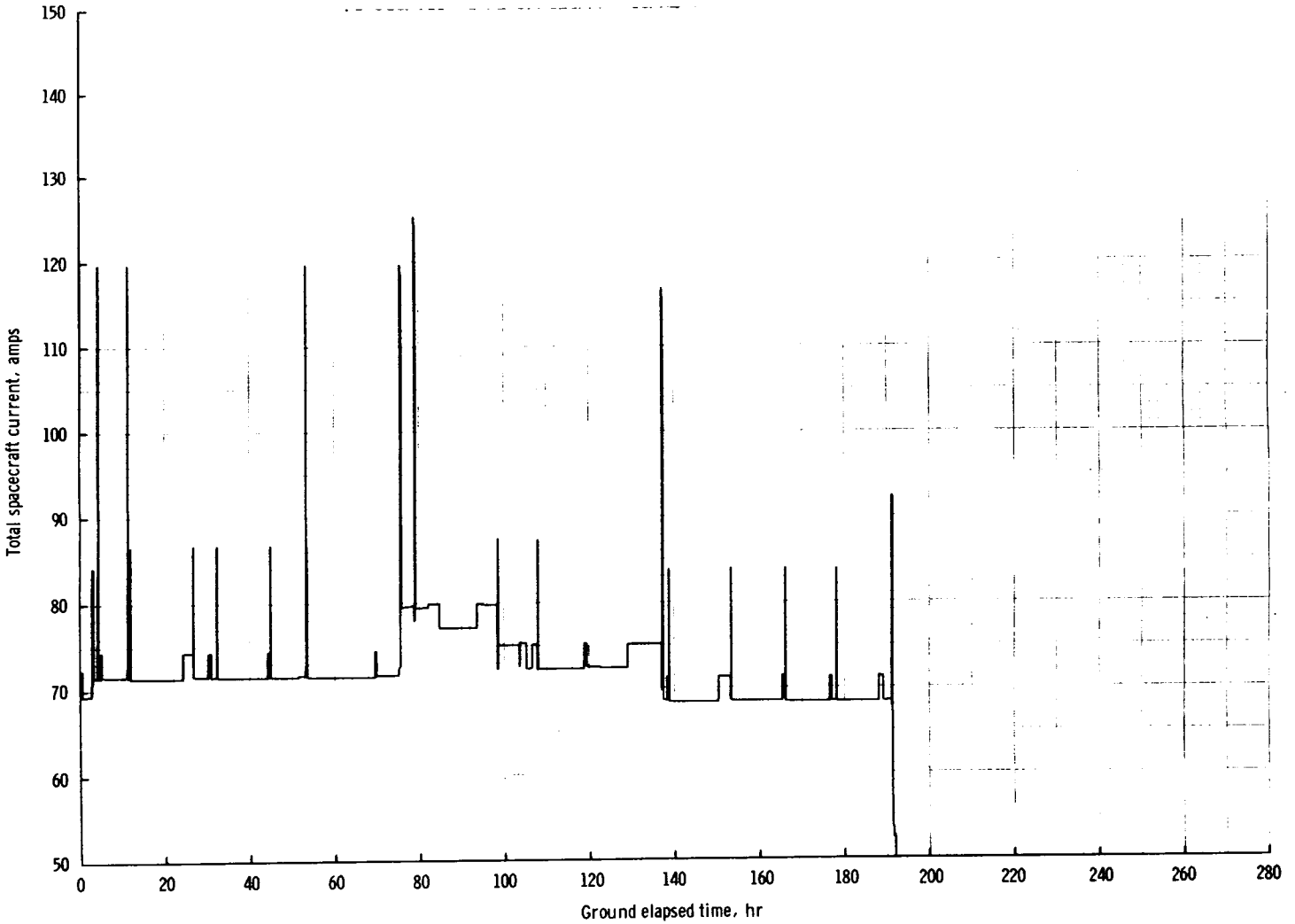



Figure 8-1. - Total CSM spacecraft current profile.

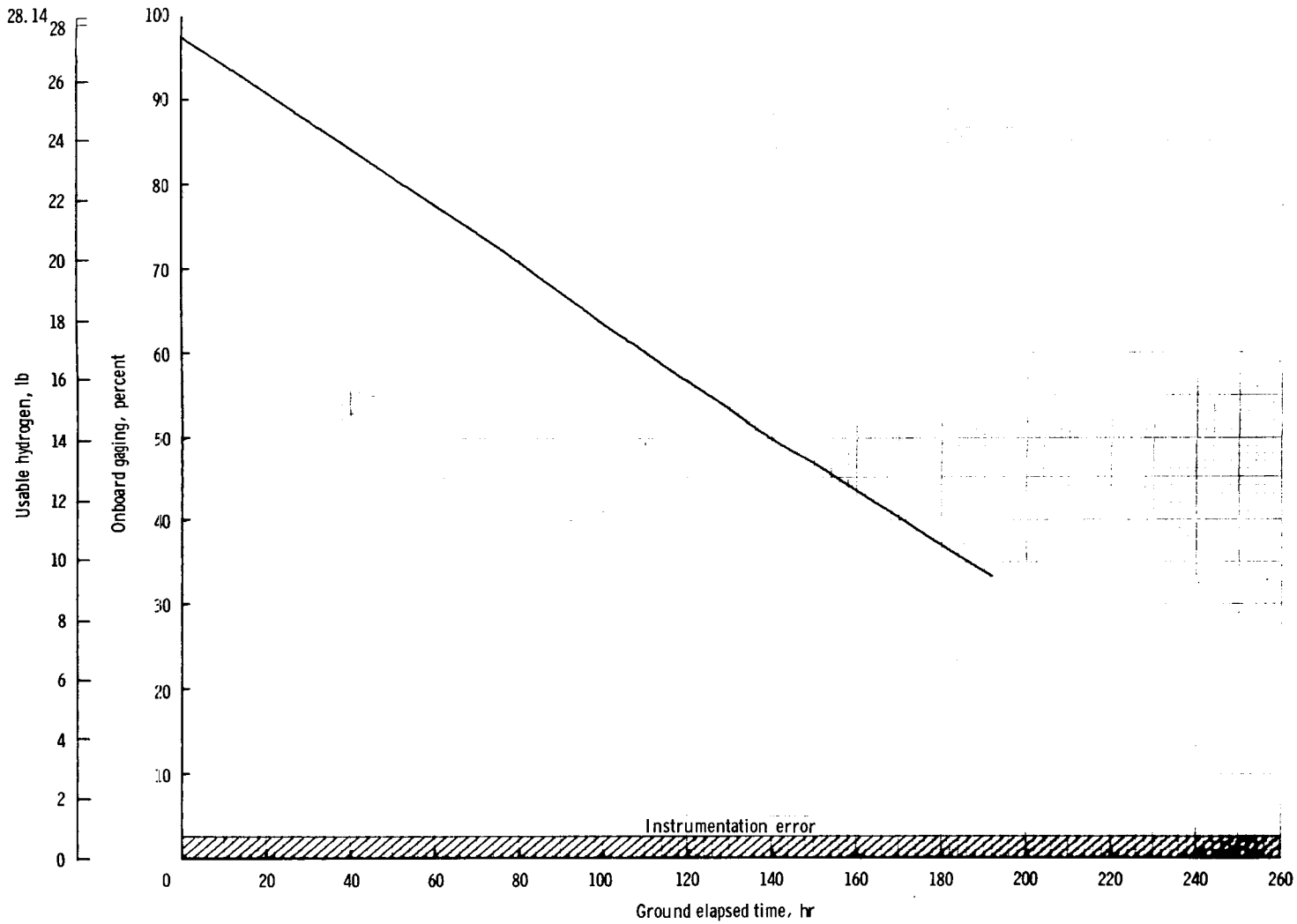



Figure 8-2. - Hydrogen remaining per tank, CSM.

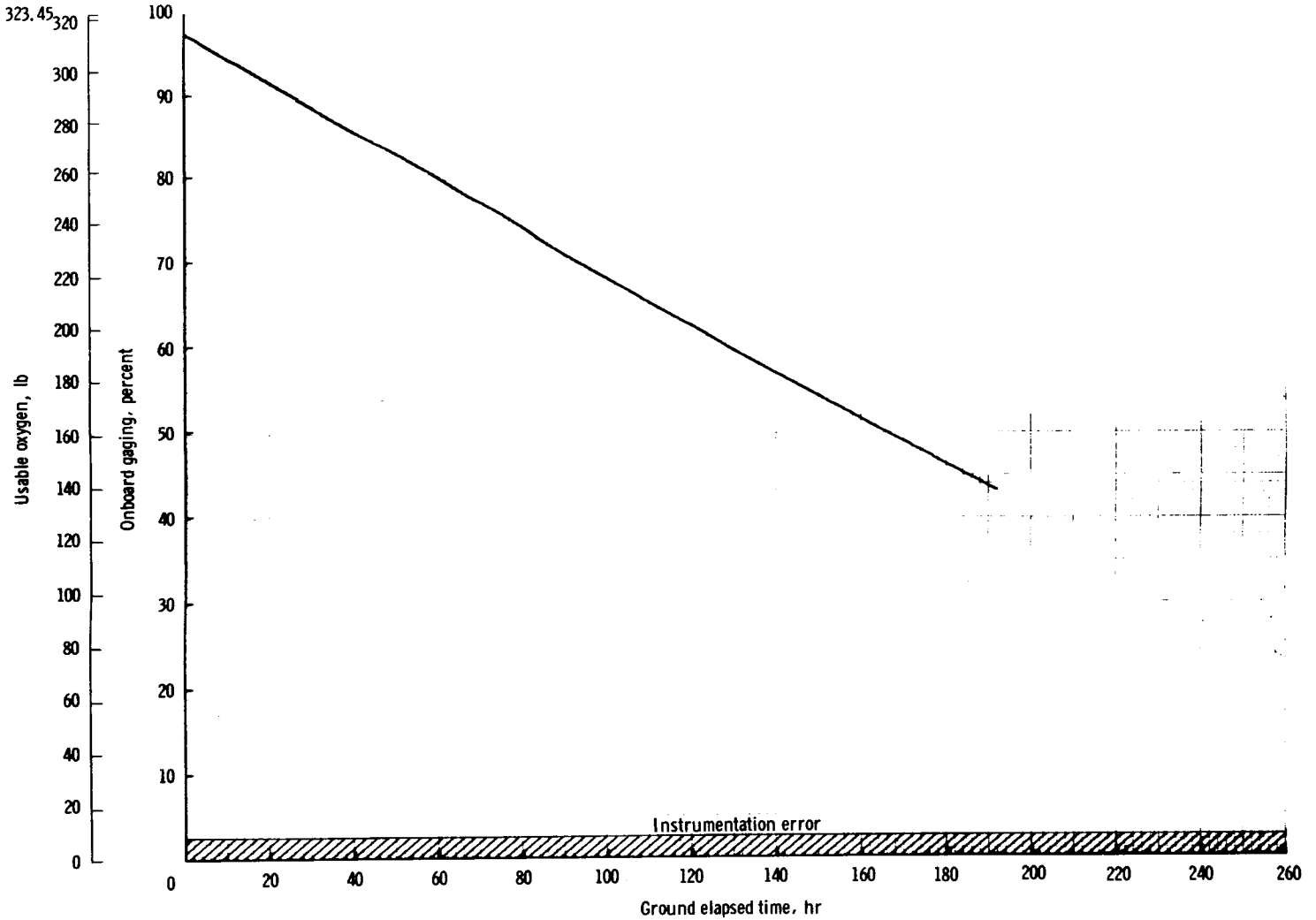



Figure 8-3. - Oxygen remaining per tank, CSM.

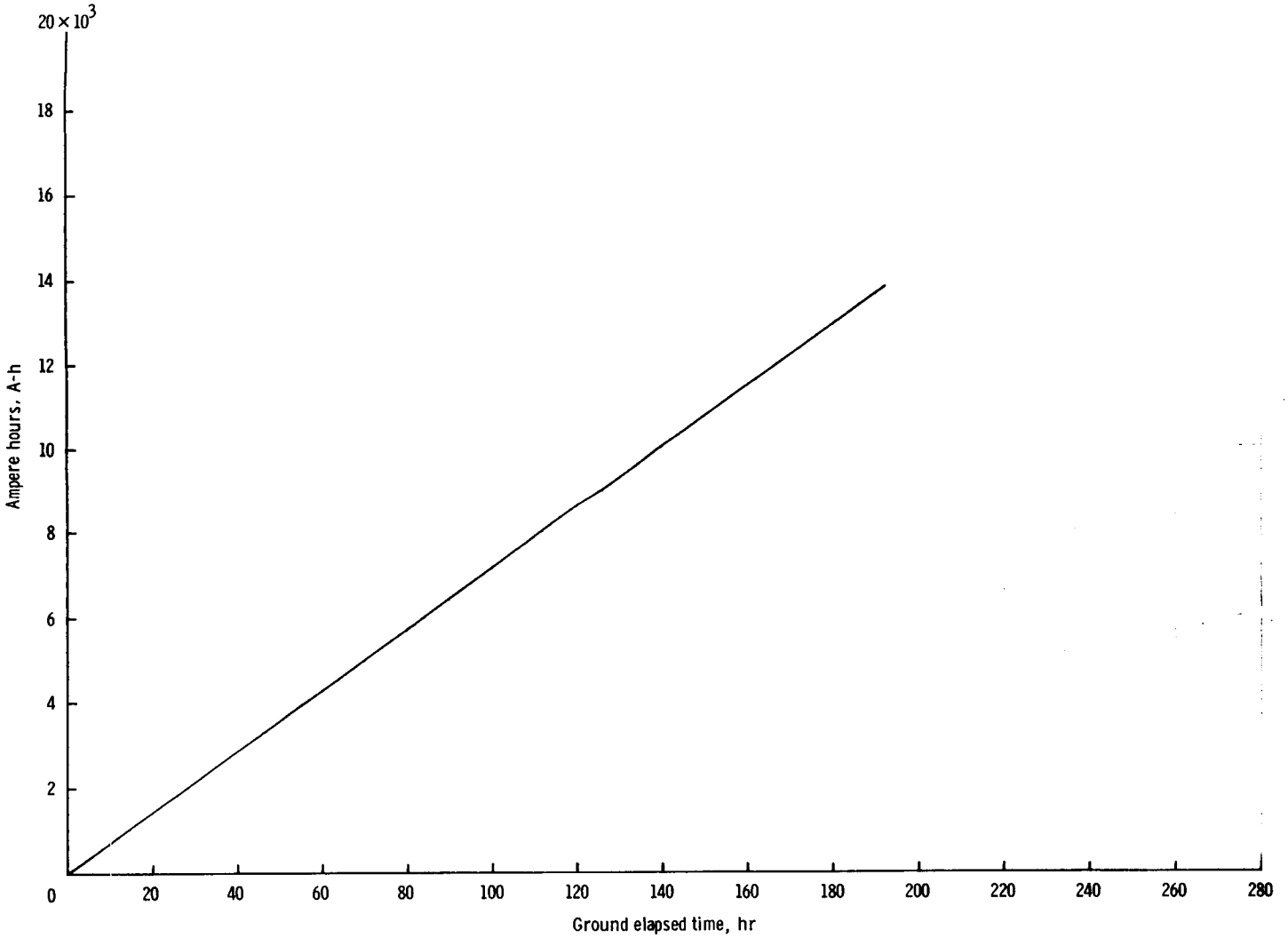



Figure 8-4. - Total DC energy.

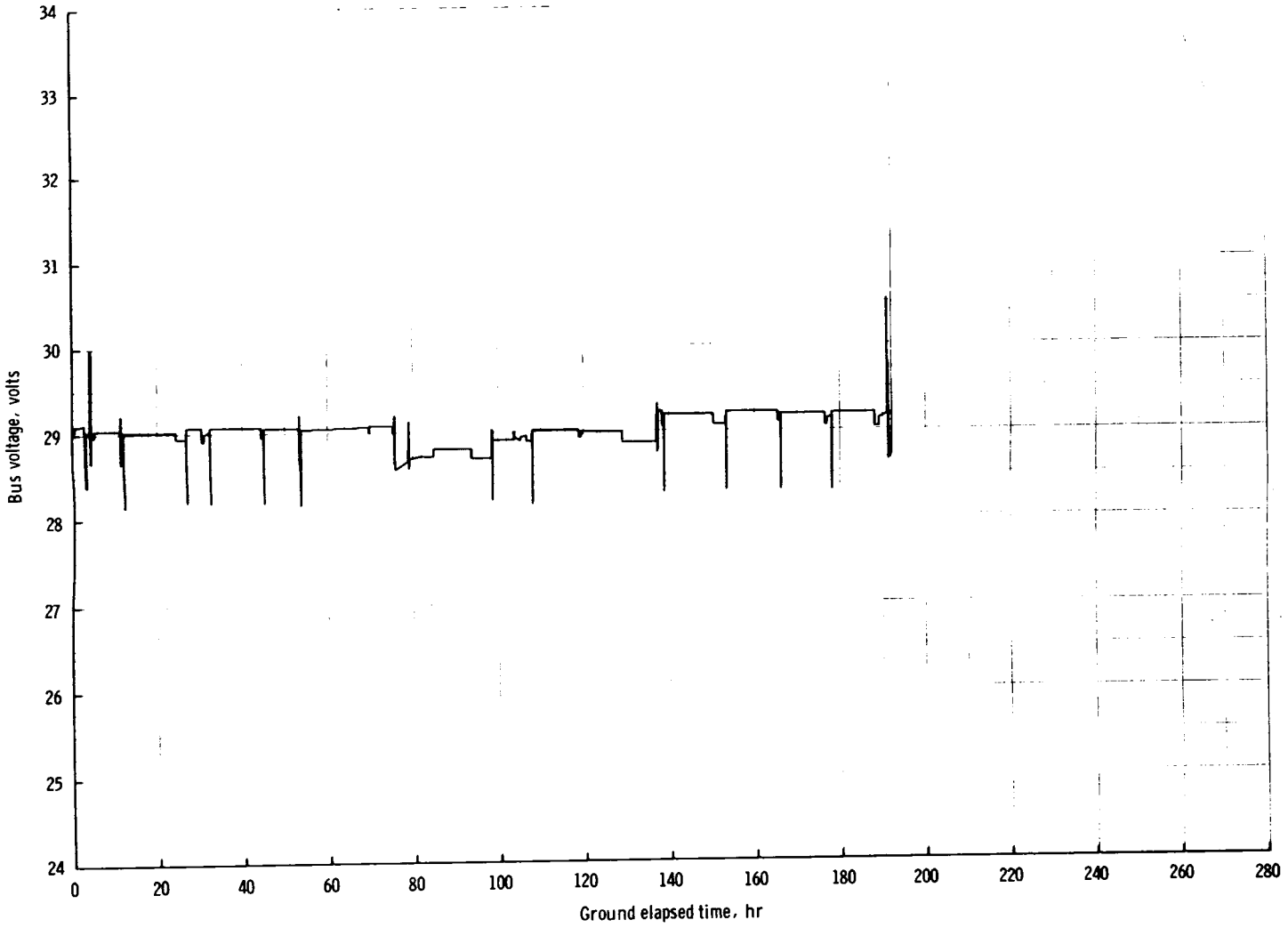



Figure 8-5. - CM bus voltage.

## 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 | $\Delta t$, 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 |

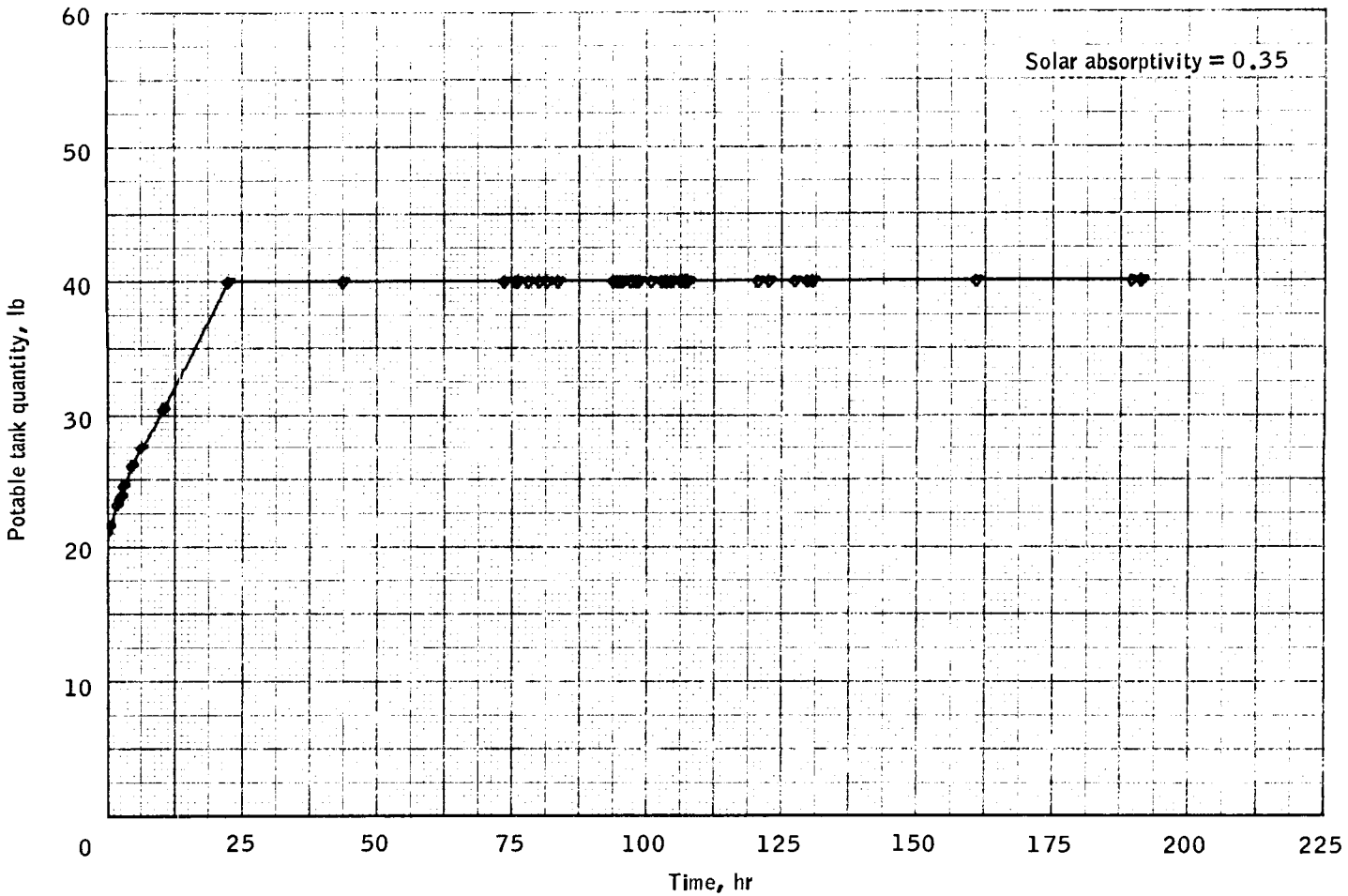



Figure 9-1.- Potable water tank quantities as a function of mission time.

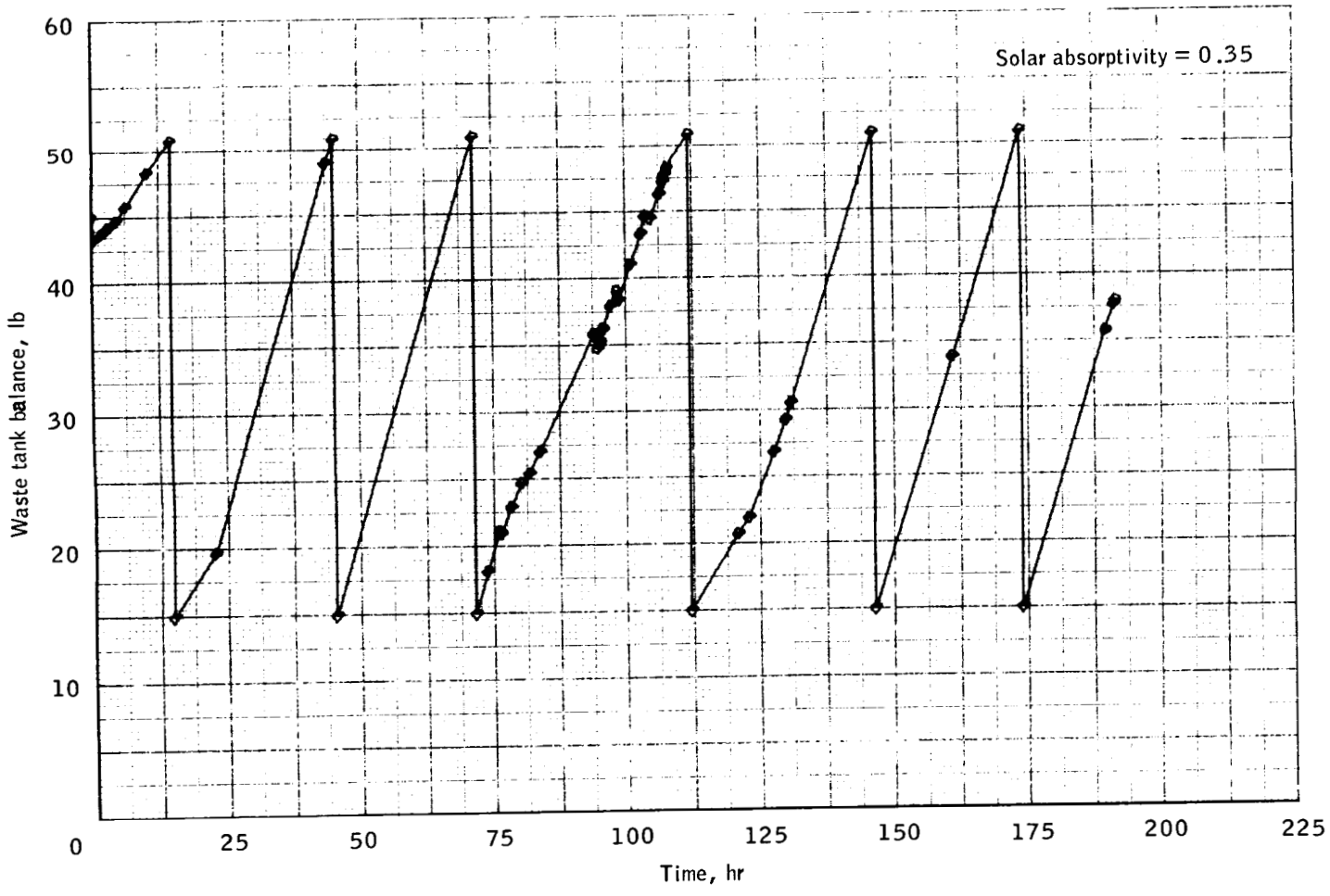



Figure 9-2.- Waste water tank quantities as a function of mission time.

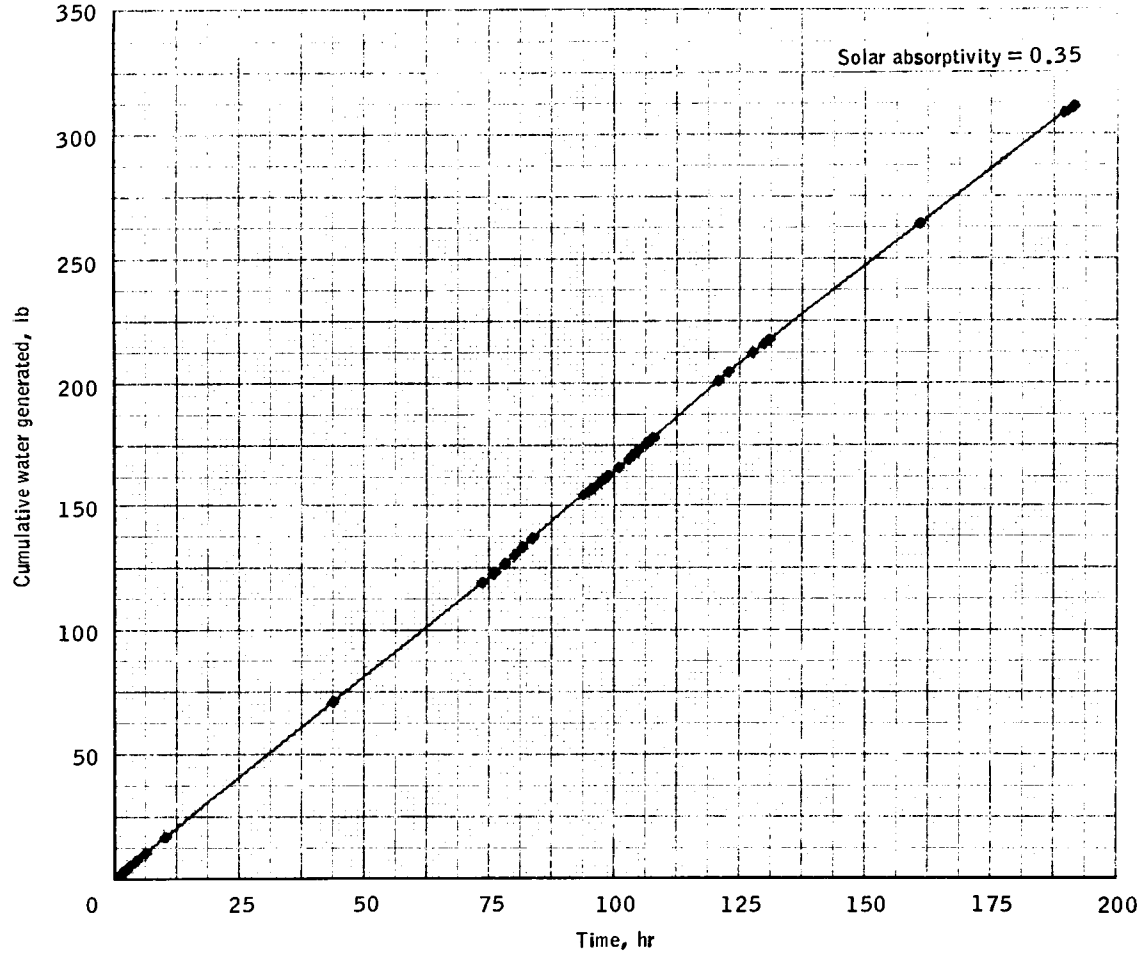



Figure 9-3.- CSM water generated as a function of mission time.

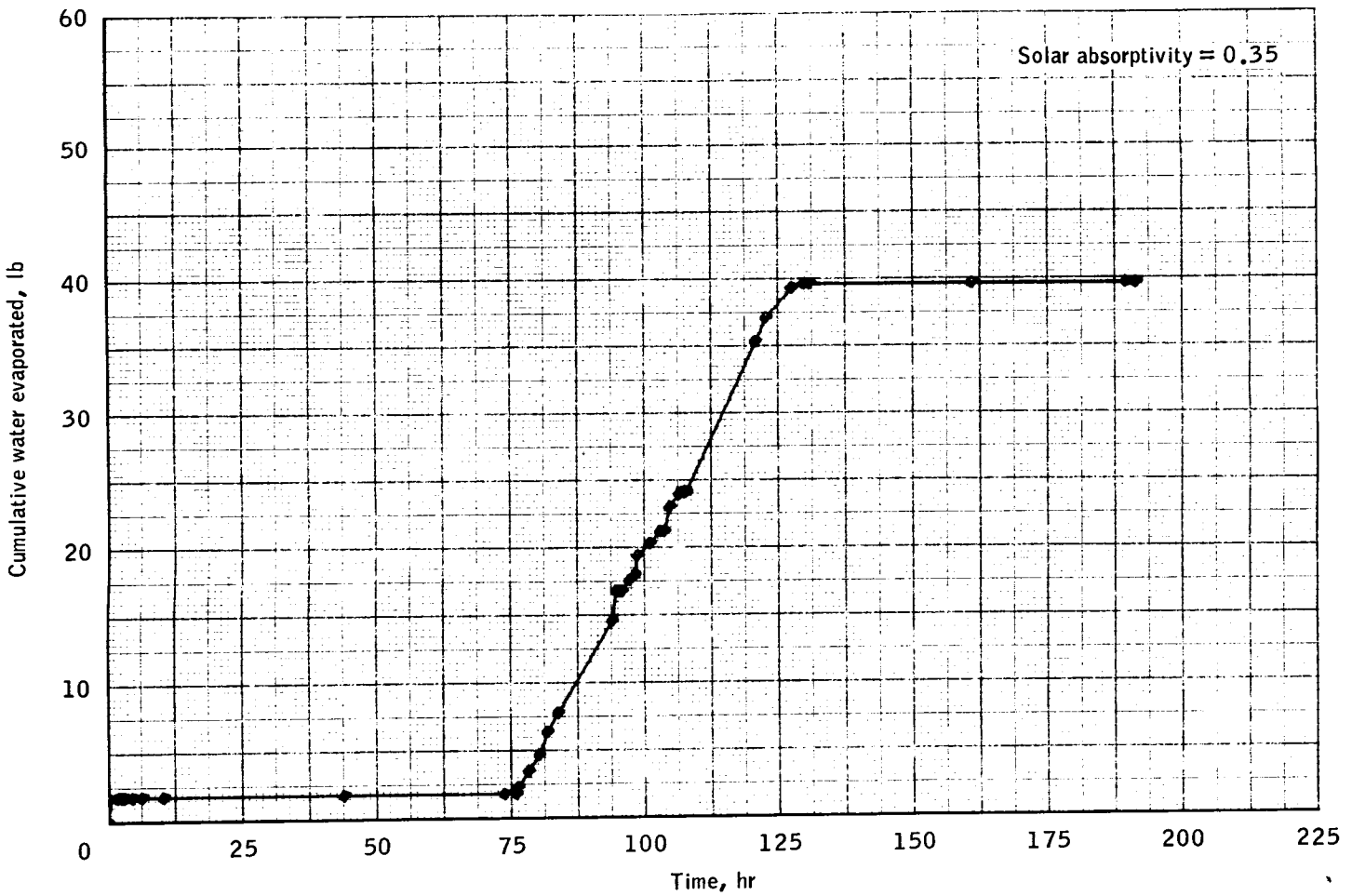



Figure 9-4.- CSM water evaporated for cooling as a function of mission time.

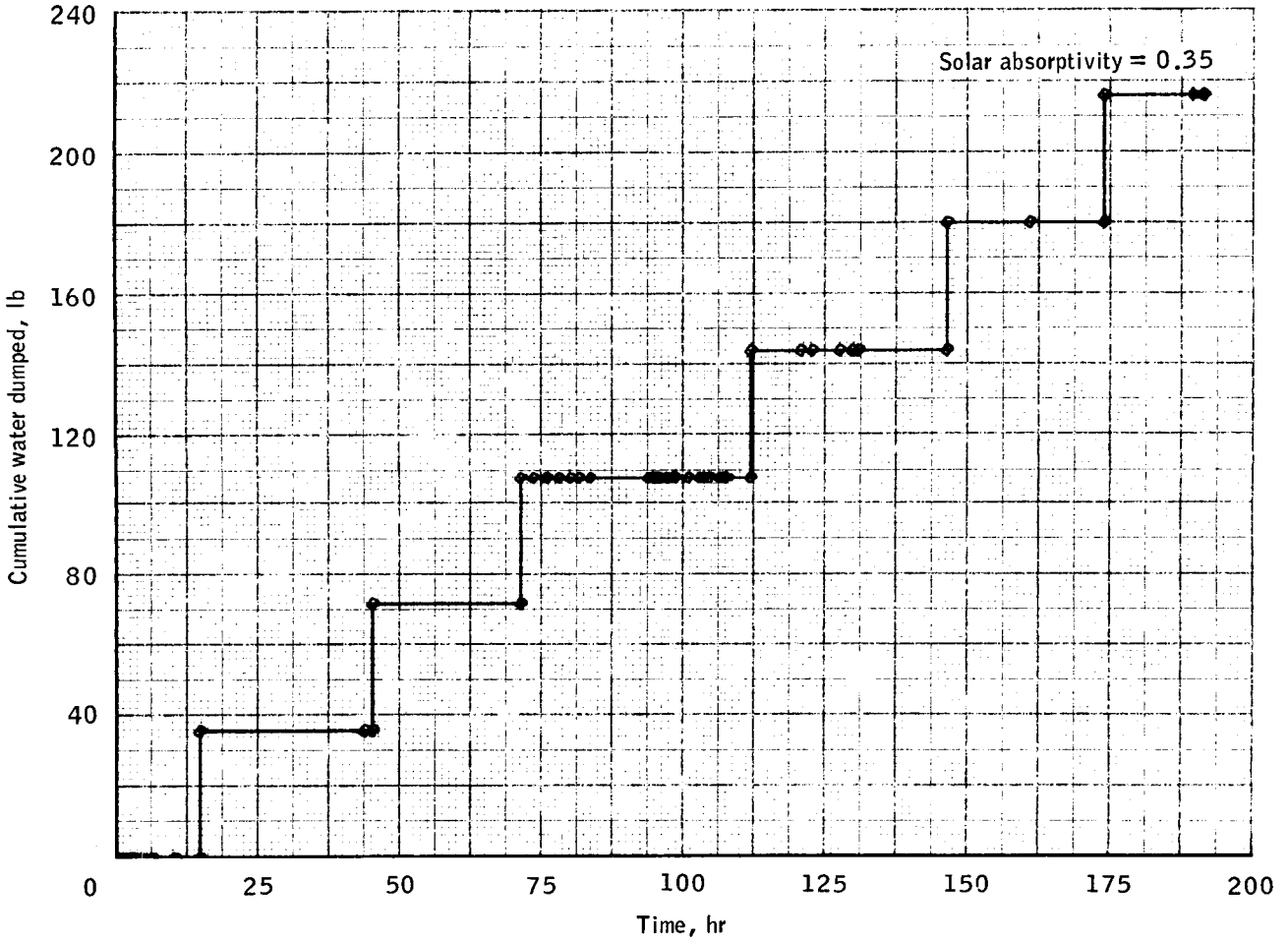



Figure 9-5.- CSM water dumped as a function of mission time.

## 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.

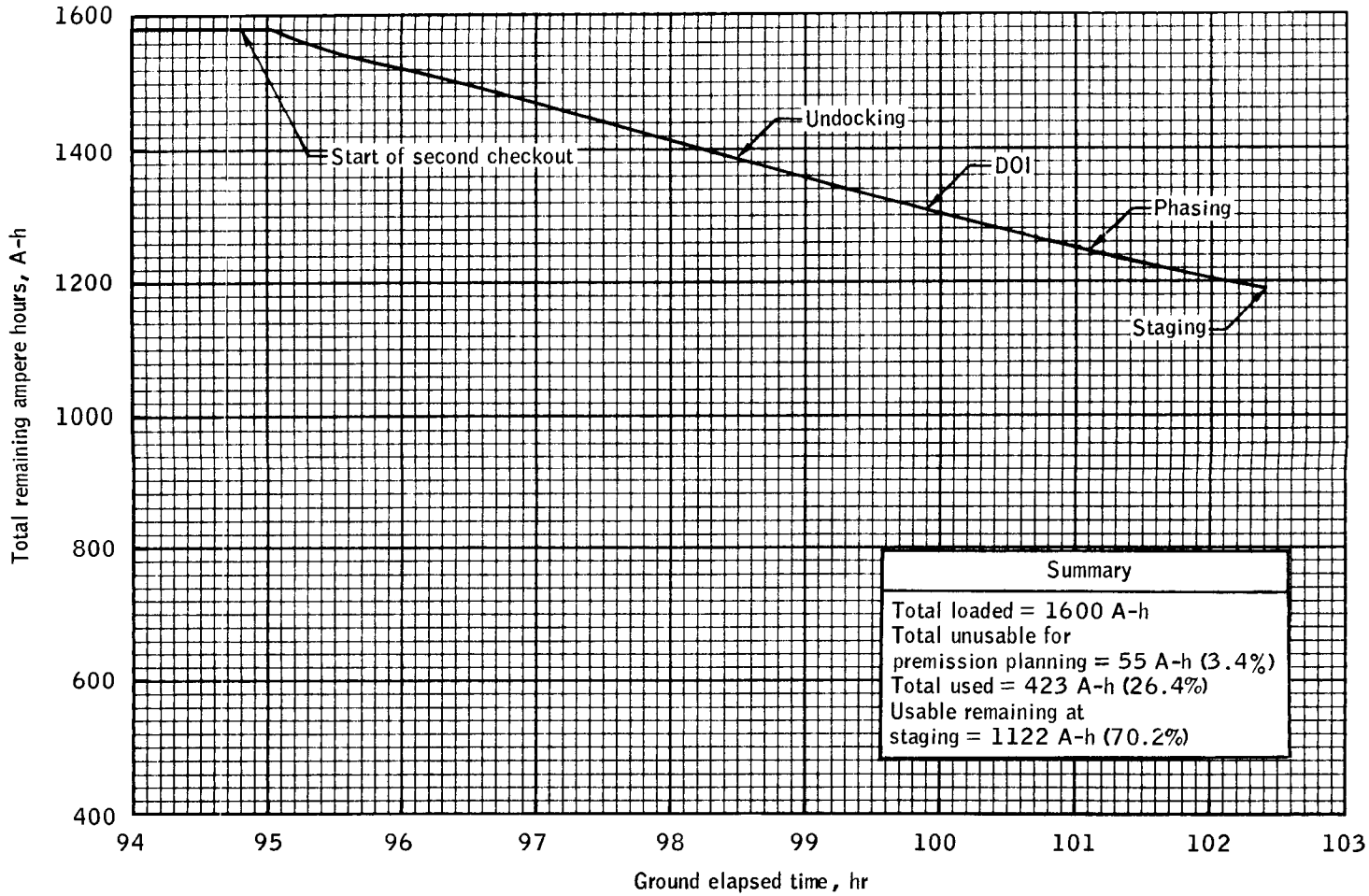



Figure 10-1.- Apollo 10 descent stage electrical power profile.

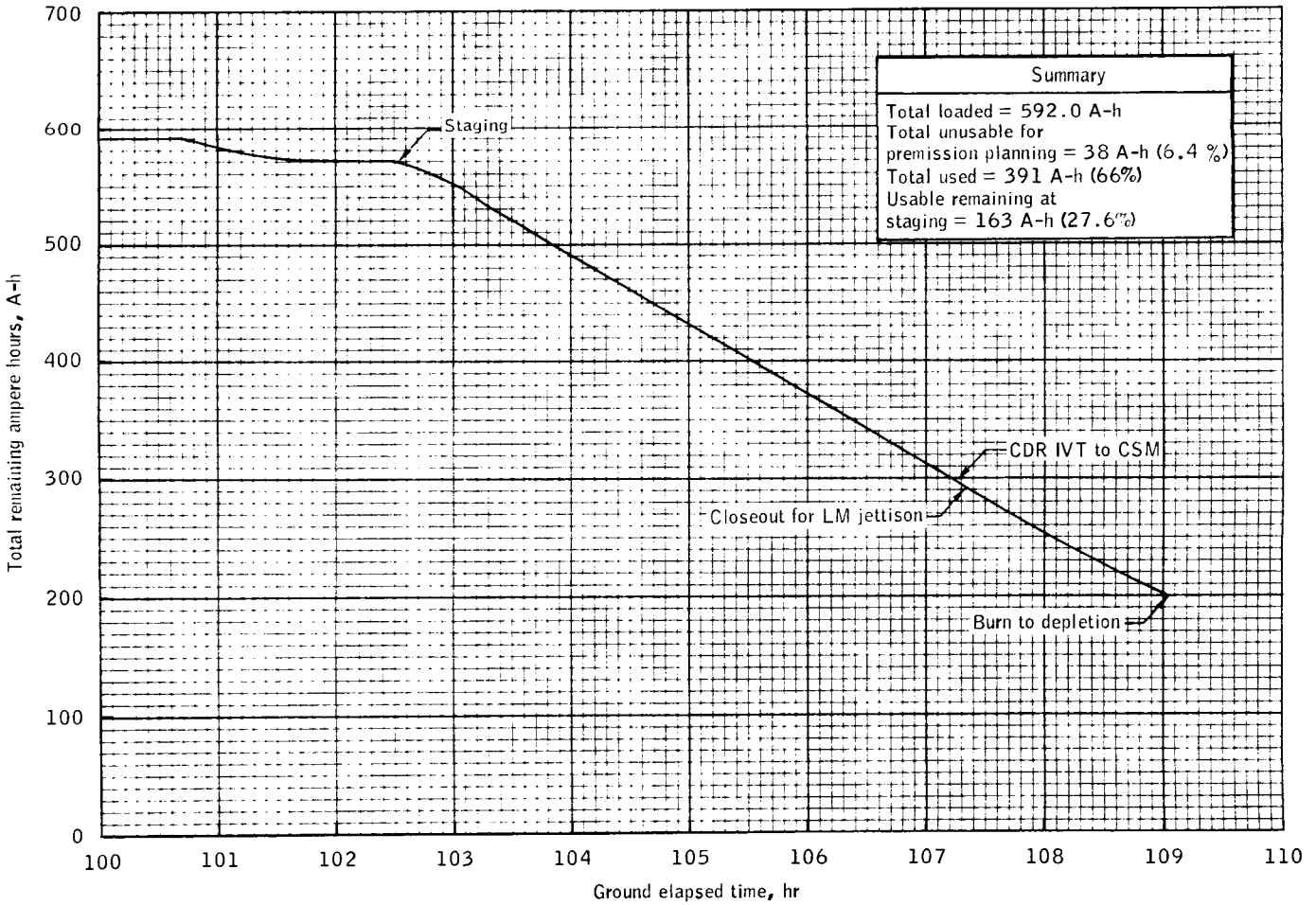



Figure 10-2.- Apollo 10 ascent stage electrical power profile.

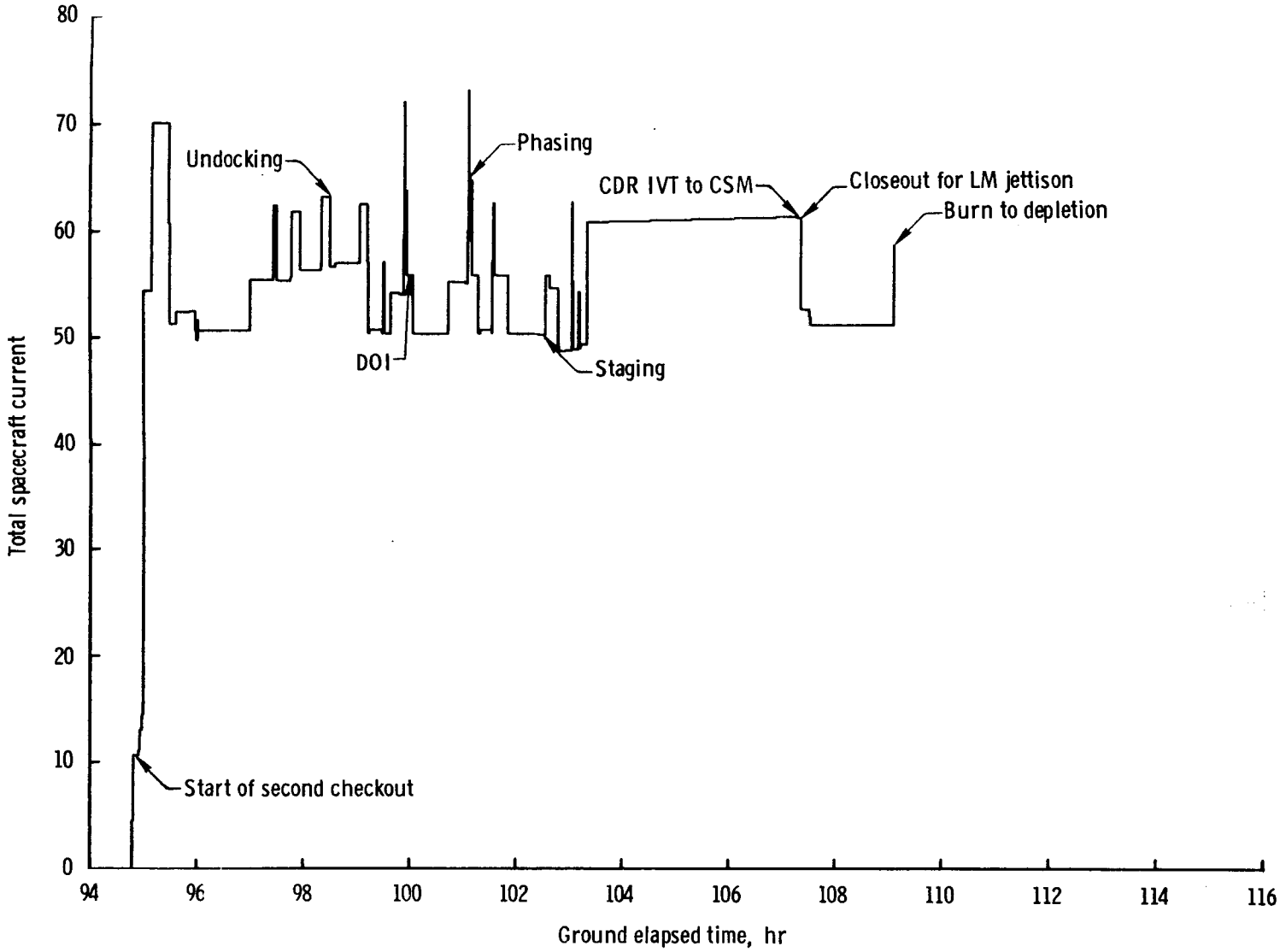



Figure 10-3. - LM-4 total spacecraft current.

## 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 |

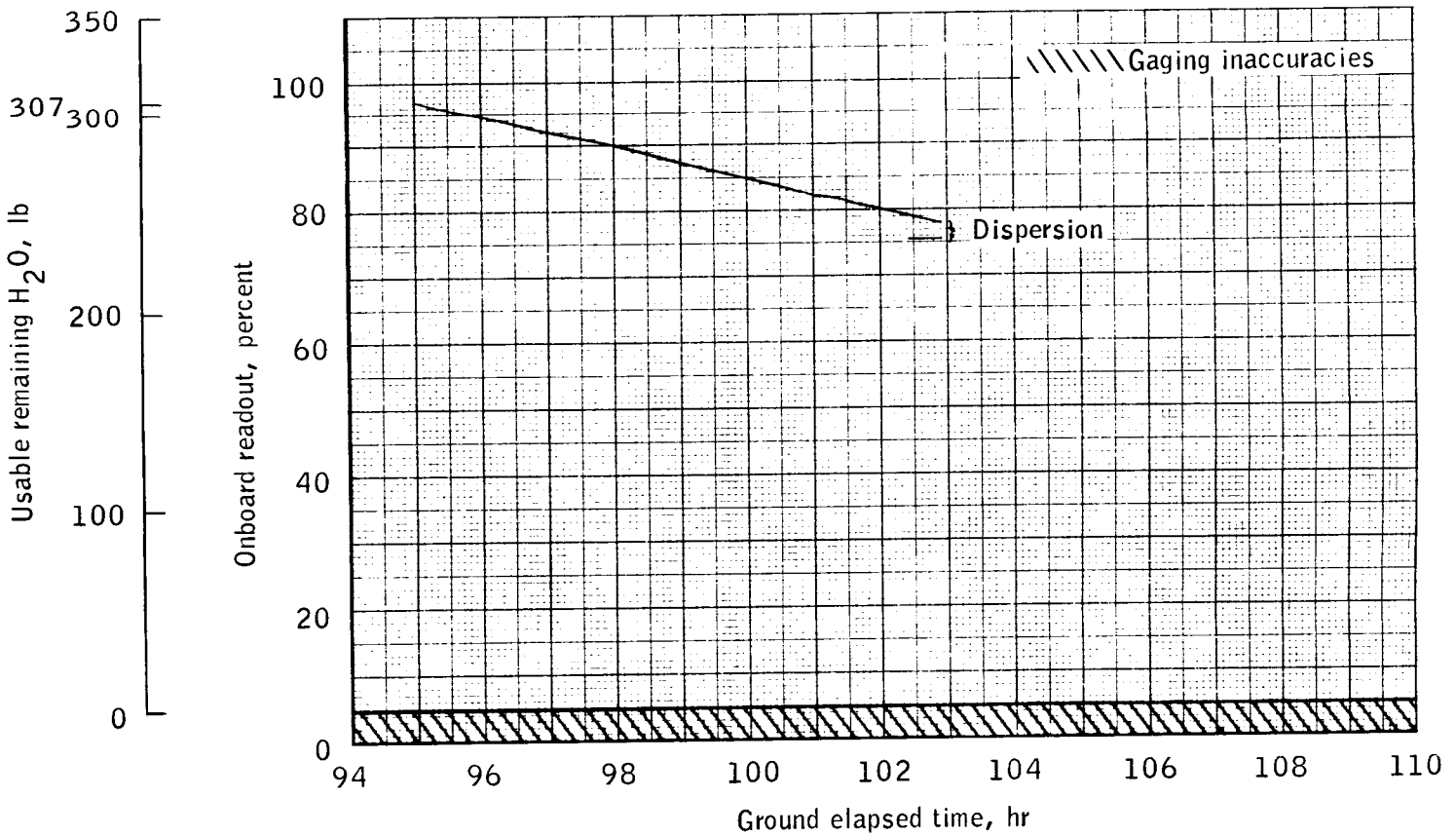



Figure 11-1.-Descent stage water tank quantities as a function of mission time.

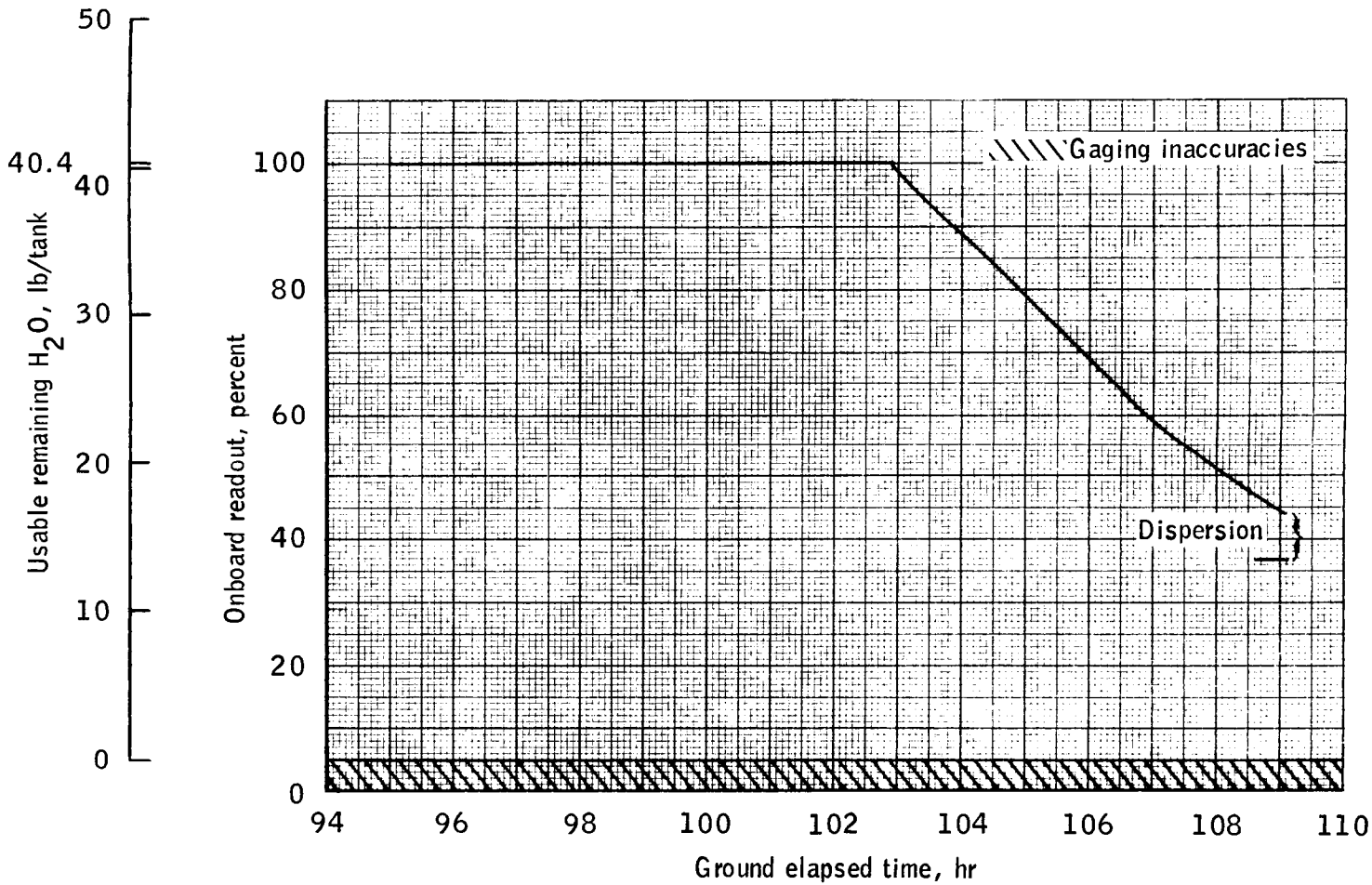



Figure 11-2.- Ascent stage water tank quantities as a function of mission time.

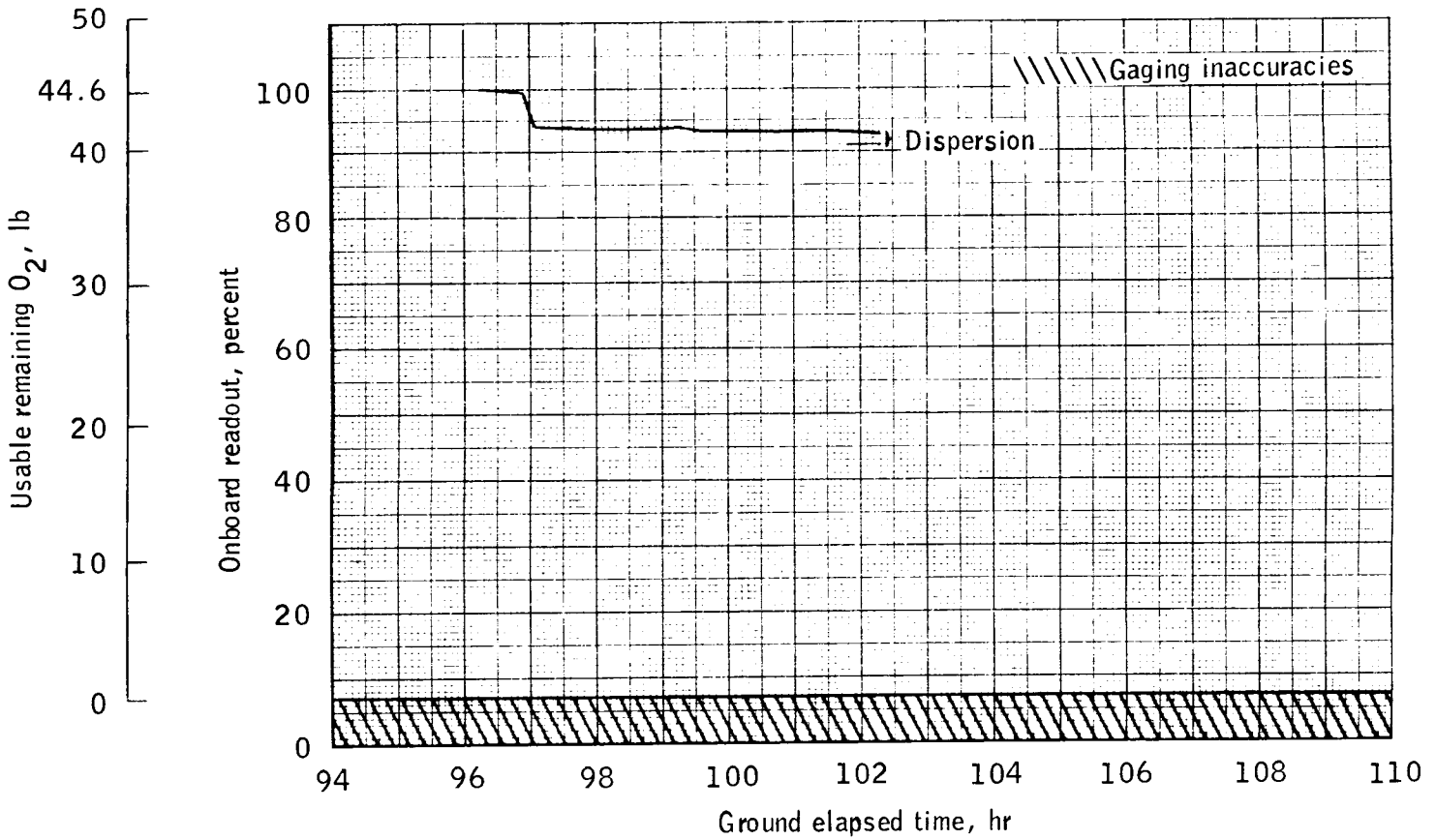



Figure 11-3.-Descent stage oxygen tank quantities as a function of mission time.

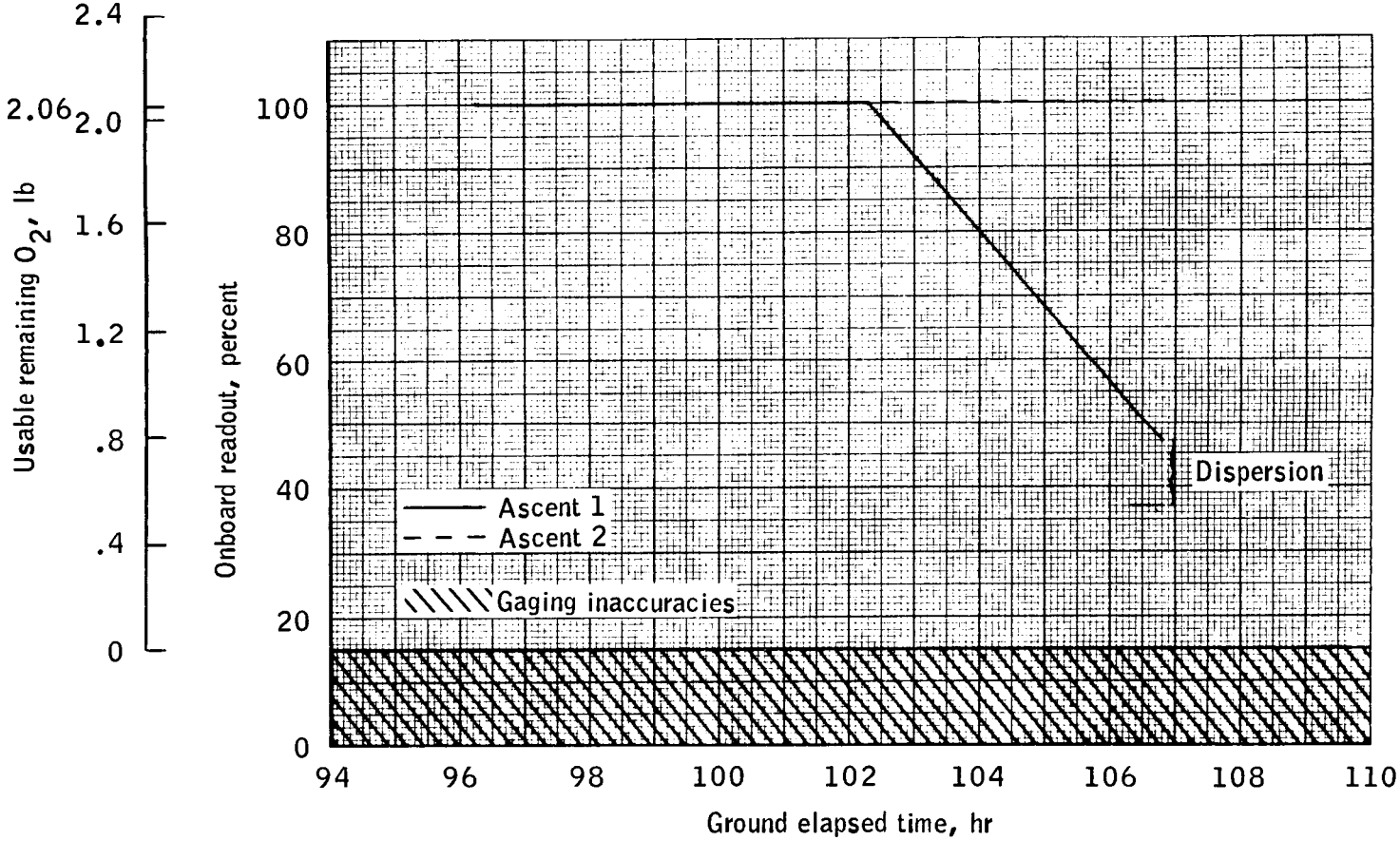



Figure 11-4.-Ascent stage oxygen tank quantites as a function of mission time.

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

| Mission time, hr | Event | RCS weight loss, lb | | | | APS weight loss, lb | LPS 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 | -- | -- | -- | 952.9 |
| 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 | -- | -- | -- |
| 108:09 | Docking to LM Jettison | 2 | 14 | 49.4 | -- | -- | -- | -- |
| 108:39 | APS burn to depletion | -- | -- | -- | -- | 2375.7 | -- | -- |
| 137:20 | LM jettison to TEI | 36 | -- | 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 | -- | -- | -- | -- |

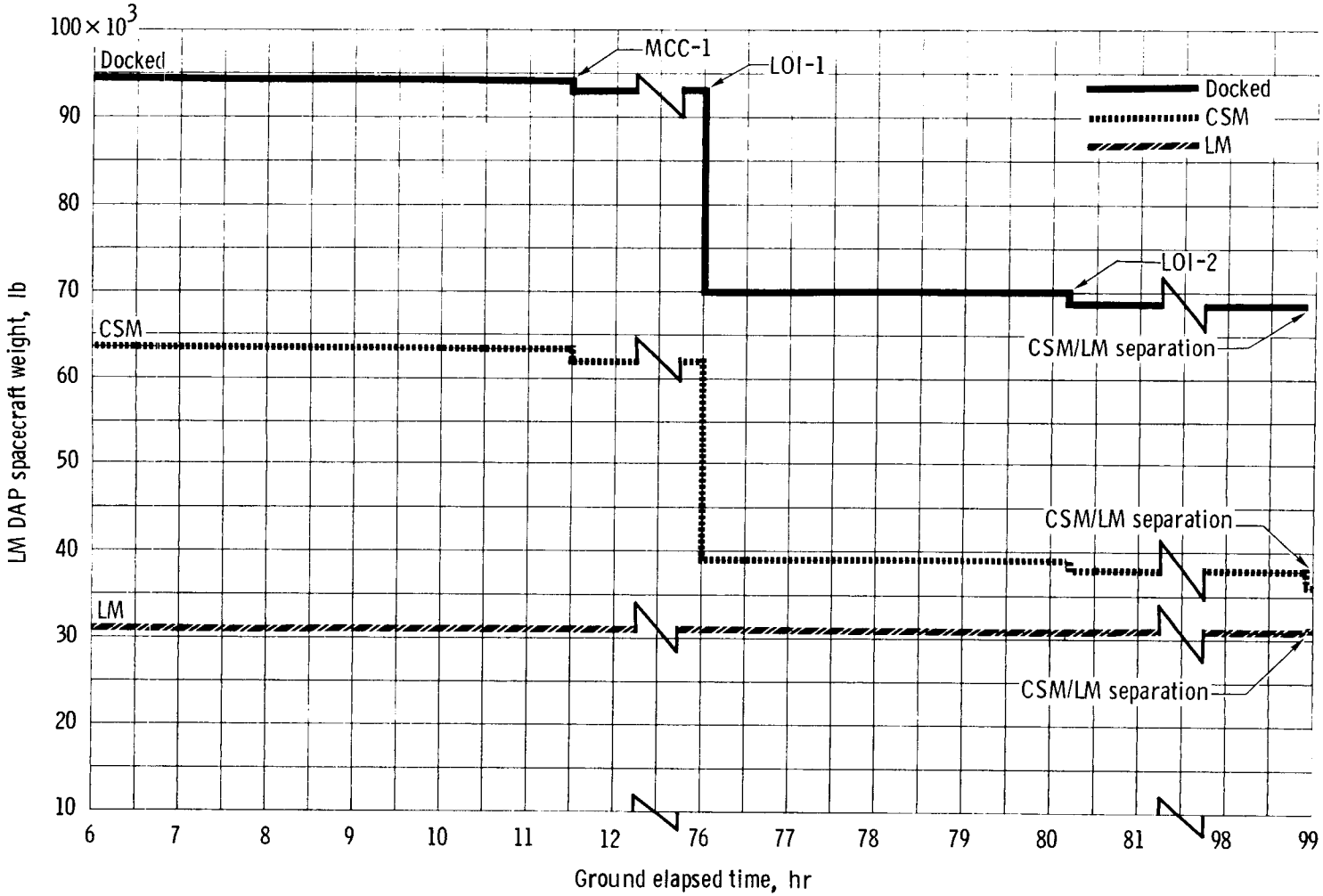



Figure 12.1.- Spacecraft weight versus ground elapsed time.

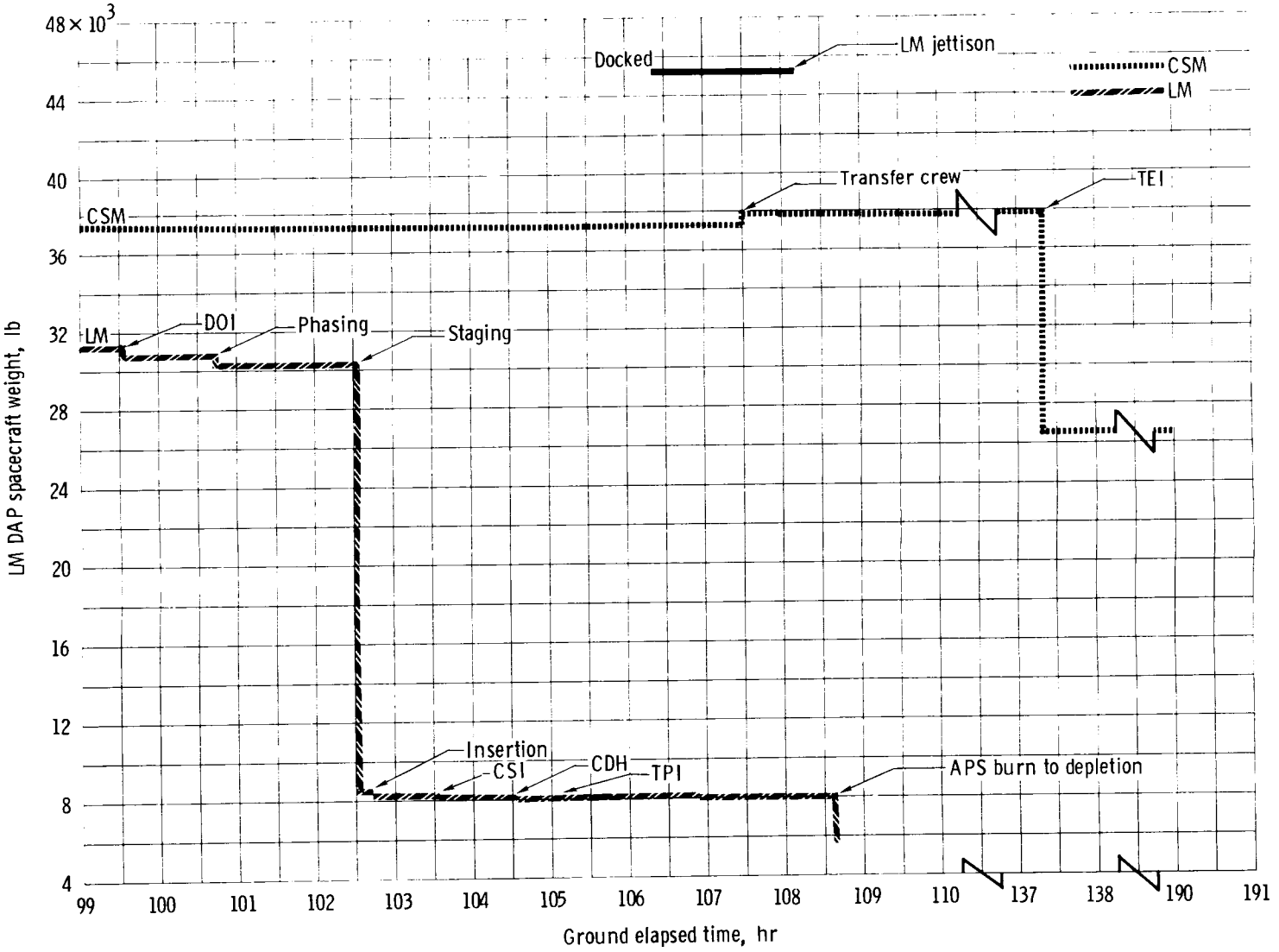



Figure 12.1.- Concluded.

## 13.0 REFERENCES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