~~CR-54753~~

CR-54804

N66-11240

(ACCESSION NUMBER)

108

(PAGES)

CR-54804

(NASA CR OR TMX OR AD NUMBER)

(THRU)

1

(CODE)

11

(CATEGORY)

FACILITY FORM 602

...ICE $

...TI PRICE(S) $

Hard copy (HC) 4.00

Microfiche (MF) .75

ff 653 July 65

GD

GENERAL DYNAMICS

~~ASTRONAUTICS~~

NOW COMBINED WITH CONVAIR

A2136-1 (REV. 6-61)

ATLAS/CENTAUR
LAUNCH-ON-TIME STUDY
FINAL REPORT (SURVEYOR MISSION)

Report Number GD/C-ACY65-001-4
7 July 1965

Contract Number NAS3-3228

M R Barlow

M. R. Barlow
Manager
System Engineering

Tech Monitor R. G. Anderson

GENERAL DYNAMICS
CONVAIR DIVISION
San Diego, California

Additional copies of this document may be obtained by contacting Centaur Resources Control and Technical Reports Department 954-4, Building 26, Kearny Mesa Plant, San Diego, California.

INTRODUCTION

Three specific launch-on-time areas are considered in this document.

a. A probability model has been developed which gives the probability of meeting a monthly launch opportunity. The results of this analysis are applied to the currently defined Centaur program.

b. An analysis of the GSE and facility systems of 36A and 36B was performed to determine contingency hold requirements and capabilities. This study updates similar studies previously reported.

c. An analysis of CSTS operations with the T-21 spacecraft and the AC-7 launch vehicle is performed.

This document is published under Contract NAS3-3228 to satisfy the requirements of NASA/Lewis Research Center Launch-On-Time Study, Sales Order 332-1-18. This report will be the last under present fiscal 1966 authorization.

SUMMARY

Throughout the launch-on-time study, numerous program improvement changes were recommended and adopted by the Centaur Project Management. Other changes were recommended or disapproved for further study.

The following table presents the recommended program changes and their current disposition.

RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE

Subject	Recommendation	Disposition
Launch day wind data reduction	Procedure change for time savings in data handling (LOT Bimonthly Report, 1 July 1964).	Adopted
Effect of hurricanes on LOT capability	Modifications to service tower at ETR 36A. (LOT Bimonthly Report, 10 November 1964, and ECP 55-628P).	Disapproved by LeRC CCB, 14 April 1965 (Reference NASA Ltr. 1431-65-329). Not adopted.
Abort-Recycle-Launch (ARL) Study	Capability for a one-day ARL based on a backup Surveyor and increased ETR manpower (LOT Bimonthly Report, 10 November 1964).	Study conducted by NASA/ LeRC request. Not adopted.
	Improved spacecraft adapter joint and fairing skirt (LOT Bimonthly Reports, 1 July and 10 November 1964).	Not adopted.
Abort-Recycle-Launch (ARL) Study (Continued)	Capability for a 24-hour ARL fluid resupply including fluid sampling, transport dewar availability, and top priority for launch complex during monthly launch opportunity (LOT Bimonthly Report, 10 November 1964).	Not adopted. Need is contingent upon 24-hour ARL requirement.

RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE (CONTINUED)

Subject	Recommendation	Disposition
Continuous LO_2 topping	Increase flexibility and hold capability of the Centaur LO_2 system. (LOT Bi-monthly Report, 10 November 1964).	Adopted. Reference NASA C.O. 384 for Complex 36A and C.O. 447 for Complex 36B.
Launch Performance Reserve (LPR)	Preplanned holds in terminal countdown of 60 minutes at T-90, and 40 minutes at T-5 for AC-5 and AC-6.	Adopted in AC-5 and AC-6 flight test plans. Open for AC-7 and on pending AC-6 countdown results.
Factory Model Work Plan	160-Day Factory Model Work Plan, including CSTS, modifications and changes. (LOT Bimonthly Progress Report, 30 September 1964).	NASA/LeRC directed report and analysis of activity. Not adopted.
ETR Model Work Plan	60-Day Work Plan for R&D launch operations, 40-Day Work Plan for operational launch operations, and Model Work Plan Weekly Reporting measured against a work standard. Weekly ETR reporting measures the LOT programming capabilities at ETR. Report (LOT Bimonthly Report, 6 January 1965).	Adopted for AC-5. Open for AC-7 and on pending further study results. Discontinued 30 June 1965.
Terminal Countdown Monitoring	Countdown monitoring system report including the following: 1. Task start and completion times for countdown events (real time). 2. Deviations to published procedures. 3. Problems encountered. 4. Explanation of system activity during hold periods in countdown.	Not adopted.

RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE (CONTINUED)

Subject	Recommendation	Disposition
	Additional audio communication channels to be recorded to include the guidance and propellant loading systems (LOT Bimonthly Report, 7 May 1965).	Adopted for AC-6 and on.
	Use of voice tape recorder to replace manual recording by the data evaluator (LOT Bimonthly Report, 7 May 1965).	Not adopted.
Terminal Countdown Length Reduction	Use gaseious helium for insulation panel purge (LOT Bimonthly Report, 7 May 1965).	CDW 65-31 weight saving Item III-39. Not adopted.
	Perform the Centaur LO_2 tanking and H_2 tank prechill operations simultaneously (LOT Bimonthly Report, 7 May 1965).	Not adopted.
Surveyor Launch Opportunities	Azimuthal constraints on the direct ascent mission (Reference GD/C-BTD65-069, 7 May 1965).	Study conducted under LOT funding. Not adopted.
	Launch window versus maneuver.	Study under LOT funding. Study funding not approved.
	Two-burn versus one-burn mission.	Study funding not approved.
Launch Predictor Program	Use to analyze status of work accomplished and analyze influence of program changes (LOT Bimonthly Report, 12 March 1965).	Adopted. Report published weekly with ETR Work Plan Report.

RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE (CONTINUED)

Subject	Recommendation	Disposition
Payload Weight Vs. Launch Window Length	Reduction in minimum window length for payload gain (LOT Bimonthly Report, 10 November 1964).	Not adopted.
Pratt and Whitney Pump Inlet Valves	Delete requirement for vacuum-drying which constrains a one-day ARL (LOT Bimonthly Report, 10 November 1964).	This is a P&WA requirement. Not adopted.
Liquid Helium Usage	Reduce LHe flow rate during ground chilldown to extend countdown hold capability (LOT Bimonthly Report, 10 November 1964).	Adopted for AC-5 and on.
	Have two Cryenco dewars available for each launch operation (LOT Bimonthly Report, 12 March 1965).	Adopted for AC-5 and on.
	Store two Cryenco dewars at supplier facility and ship to ETR just prior to need (LOT Bimonthly Report, 12 March 1965).	Not adopted.
	Use GHe alone for purge of the Centaur LH_2 tank in place of GN_2 and GHe to eliminate a time constraint to a one-day ARL (LOT Bimonthly Report, 10 November 1964).	Adopted, effective AC-5 and on.
	Use a continuous gas analysis sampling system to reduce the Centaur LH_2 purge constraint to a one-day ARL (LOT Bimonthly Report, 10 November 1964).	Not adopted. Must be considered if one-day ARL is required.

RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE (CONTINUED)

Subject	Recommendation	Disposition
Range Safety	Remove 6-hour limitation for RSC checkout which constrains countdown hold capability. (LOT Bimonthly Report, 10 November 1964).	Adopted. Limitation is 10. 5 Hours for R&D flights.
36B LO_2/LN_2 Subcooler	Provide remote level sensing and refill capability to increase system hold capability. Existing design can only support a maximum hold of 74 minutes, which is unacceptable.	Not adopted.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

SECTION I

PROBABILITY OF LAUNCH DURING A MONTHLY LAUNCH OPPORTUNITY, 1965 - 1968

1.1 INTRODUCTION

1.1.1 SCOPE. A probability model has been developed which gives the probability of the Atlas/Centaur meeting a monthly launch opportunity. The model includes surface winds, winds aloft, number of days in the launch opportunity, lunar lighting restraints, and turnaround time in the event of an abort. The model is based on past performance of Atlas vehicles at the Eastern Test Range (ETR).

Preliminary results of the analysis using this model are given in Table 1-1 for the currently defined Centaur program.

TABLE 1-1. PROBABILITY OF LAUNCH DURING MONTHLY LAUNCH OPPORTUNITY, ATLAS/CENTAUR VEHICLES

Vehicle	Month	Probability of Launch During Monthly Launch Opportunity, P_L
AC-6	July '65	0.92
AC-7	October '65	0.55
AC-8	January '66	0.64
AC-9	April '66	0.56
AC-10	May '66	0.78
AC-11	July '66	0.81
AC-12	October '66	0.70
AC-13	January '67	0.23
AC-14	April '67	0.56
AC-15	July '67	0.93

1.2 HISTORICAL DATA

1.2.1 ATLAS D-SERIES PROFILE. The launch history of Atlas D-Series vehicles at ETR was analyzed for statistical data. These vehicles consisted of R&D, Project Mercury, Atlas/Able, Midas, Atlas/Centaur, Ranger, Atlas/Agena, OGO, Project Fire and Mariner. As shown in Table 1-2, there were 124 launch attempts for 66 successful launches, giving a 0.53 factor of success.

TABLE 1-2. ATLAS D-SERIES LAUNCH HISTORY

Month	No. Launch Attempts	No. Successful Launches	No. of Weather Aborts
January	11	5	4
February	8	4	4
March	4	2	0
April	12	5	3
May	10	6	0
June	11	5	0
July	13	6	0
August	8	5	0
September	12	7	0
October	17	8	1
November	11	8	0
December	7	5	2
TOTALS	124	66	14

A launch attempt is defined as a launch operation that begins with an official range countdown and terminates with either a successful launch or an abort.

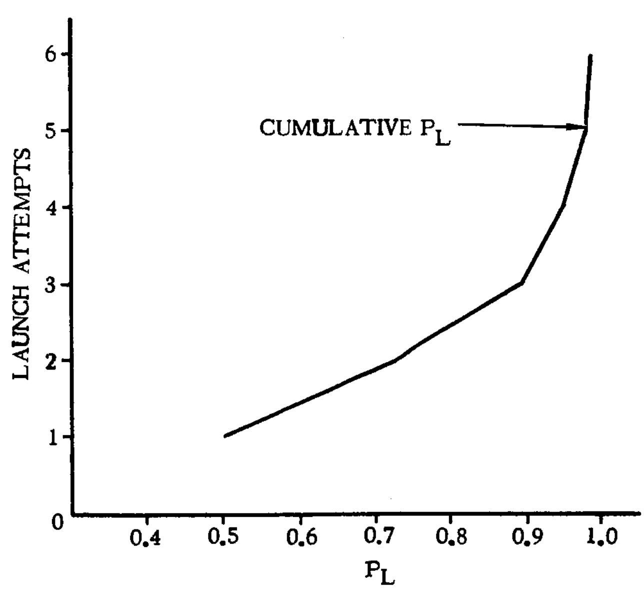
1.3 PROBABILITY MODEL

1.3.1 MODEL APPLICATION. The probability of a successful launch attempt, P_L, during a given monthly launch opportunity is equal to the conditional probability of a successful launch of the nth attempt, i.e.,

$$P_L = p_1 + qp_2 + q^2 p_3 + \cdot \cdot \cdot + q^{n-1} p_n,$$

Where: P_L = probability of launch during a monthly opportunity,
p_n = probability of success of an individual launch attempt,
n = number of individual launch attempts,
$q = (1 - p)$ = probability of failure of an individual launch attempt,
$p_1 = p_2 = \cdot \cdot \cdot = p_n$, and
$q_1 = q_2 = \cdot \cdot \cdot = q_n = q$.

The probability model works in the following manner; assuming a probability of individual launch success of $(p_n) = 0.5$, there is a cumulative probability with each succeeding launch attempt as shown in Figure 1-1.



4K01LV

Figure 1-1. Probability of Launch P_L versus Number of Launch Attempts

1.3.2 MODEL IMPOSED CONDITIONS. The probability of an individual launch success for a given launch window (as opposed to the monthly launch opportunity) has been treated in Reference 9. This probability is directly dependent on the hold capability of the system and preplanned holds in the terminal countdown and is, therefore, not considered a factor in the present monthly opportunity probability model. Application of this model will, however, include conditions imposed by ground winds, winds aloft, number of days in the launch opportunity imposed by lunar lighting restraints, and turnaround time in the event of an abort.

1.4 LAUNCH OPPORTUNITIES

1.4.1 DEFINITION. A launch opportunity is defined as a period of time, containing one or more days, during which performance of the Surveyor spacecraft mission is feasible. These days are generally successive. Unless otherwise stated, the launch opportunities considered are based on those opportunities presented in Reference 3, Direct Ascent Case A and Parking Orbit Ascent, Tables 1 and 4 respectively.

1.4.2 REQUIREMENTS. Each launch opportunity was examined, and only those windows in the opportunities which met or exceeded the minimum hours of sunlight remaining at the lunar landing site were used. The minimum hours of sunlight include those gained by shifting the landing site as much as 26 degrees longitude, east or west, on the lunar equator. As an example, during the March 1966 launch opportunity, an additional launch window is gained by shifting the landing site 26 degrees west longitude for the launch window giving on arrival date of 17 March. This window meets the lunar lighting requirements.

1.5 WEATHER EFFECTS ON PROBABILITY OF LAUNCH

1.5.1 ABORT DATA DUE TO WEATHER. Launch wind availability data was gathered from Reference 1,2,4, and 6. Actual launch aborts because of weather are given in Table 1-2.

In the 124 launch attempts of Atlas D-Vehicles at ETR (Table 1-2), 14 aborts were due to weather. Removing these aborts results in a probability of launch, p_n, for any single launch attempt (minus weather) of 0.6000 [66/(124-14) or 66/110]. Combining this launch probability with the wind "launch availability" for a given month, a probability of success (p_W) for any single launch attempt for that particular month is obtained as shown in Table 1-3.

TABLE 1-3. PROBABILITY OF SUCCESS FOR A SINGLE LAUNCH ATTEMPT (p_w) BY MONTH BASED ON WIND LAUNCH AVAILABILITY

Month	Wind Launch Availability			Probability of Launch
	Aloft (p_a) (AC-7 thru AC-15)	Ground (p_g) (AC-6)	Total ($p_a \cdot p_g$)	(p_w) = ($p_a \cdot p_g \cdot p_n$)
January	0.50	0.76	0.380	0.2280
February	0.33	0.76	0.251	0.1506
March	0.33	0.74	0.244	0.1464
April	0.50	0.79	0.395	0.2370
May	0.80	0.82	0.656	0.3936
June	0.90	0.90	0.810	0.4860
July	1.00	0.97	0.970	0.5820
August	1.00	0.93	0.930	0.5580
September	0.90	0.79	0.711	0.4266
October	0.80	0.69	0.552	0.3312
November	0.50	0.74	0.370	0.2220
December	0.34	0.78	0.265	0.1590

The results of applying the probabilities of launch of Table 1-3 to the currently defined Centaur program are given in Table 1-1.

The history of weather aborted launch attempts is shown in Table 1-4. The p_w for each month having weather aborts is included for comparison with percentage of total aborts here to weather.

TABLE 1-4. ABORTS DUE TO WEATHER

Month	Launch Attempts	Total Aborts	Weather Aborts		p_w from Table 1-3
			No. of Aborts	Percent of Total	
January	11	6	4	67	0.228
February	8	4	4	100	0.1506
April	12	7	3	43	0.237
October	17	9	1	11	0.3312
December	7	2	2	100	0.1590

Note that all weather aborts occurred during months having low probability of launch, p_W in Table 1-3. No weather aborts were recorded for the months having a high p_W from May through September.

1.6 TURNAROUND TIME VERSUS PROBABILITY OF LAUNCH

1.6.1 TURNAROUND CRITERIA. The space vehicle and launch site turnaround capability have a direct effect upon the probability of launch. The number of launch opportunity days (n'th term in probability model) is governed by the total number of days within a launch opportunity, and the number of days required for a turnaround operation in the event of an aborted launch attempt. A matrix for "n values" is presented in Table 1-5.

TABLE 1-5. LAUNCH OPPORTUNITY DAYS

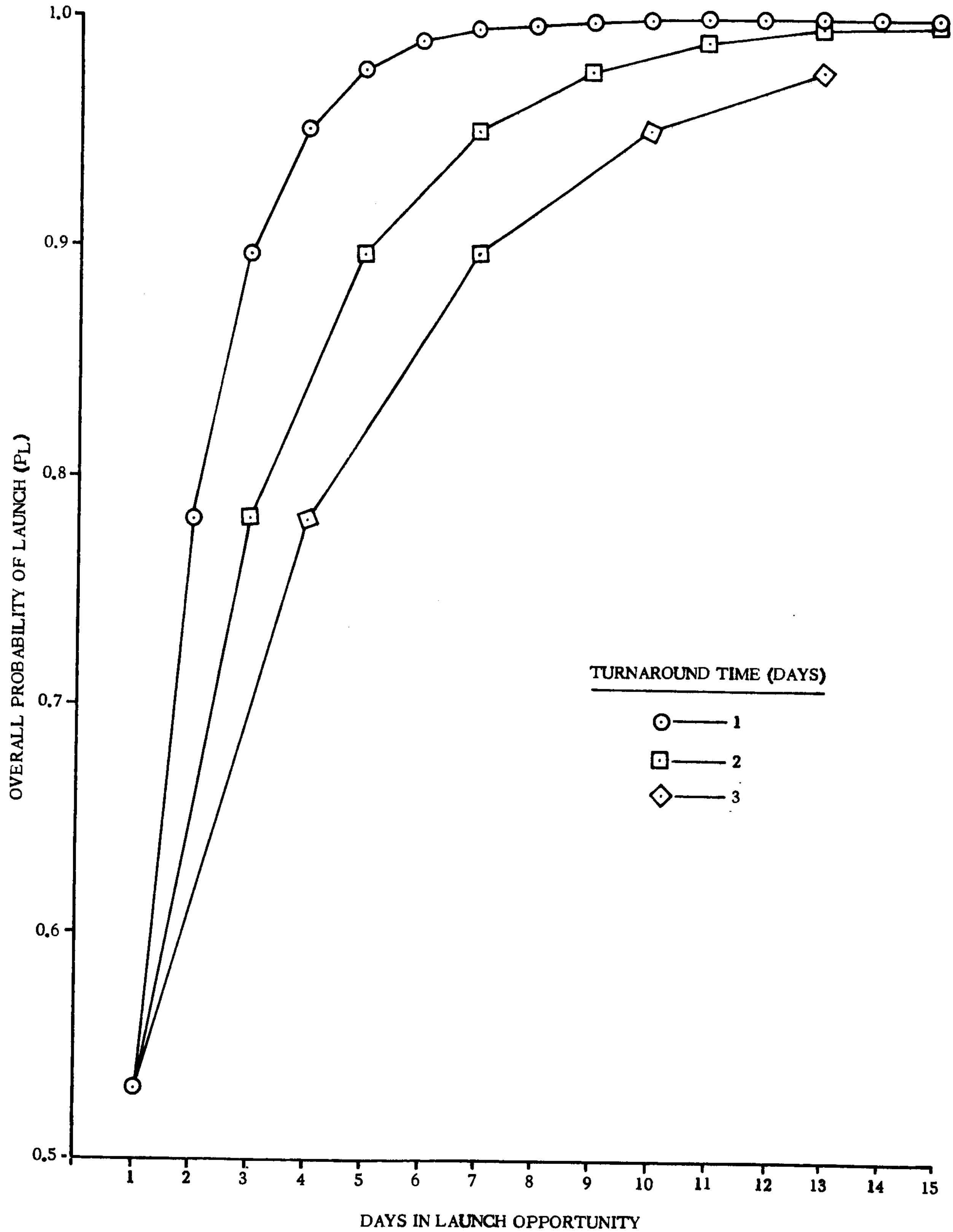
Turnaround Time (Days)	Number of Days Available in Launch Opportunity 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
3	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5
	Number of Launch Opportunity Days														

1.6.2 EFFECTS OF TURNAROUND TIME ON LAUNCH PROBABILITY. Table 1-3, gives a probability of success for an individual launch attempt p_W, of 0.52. This p_W is used in paragraphs 1.5 through 1.8 to show the effects on P_L the probability of launch during a monthly opportunity, of turnaround time, number and length of launch windows, and types of ascent. The monthly launch wind effects, given in Table 1-3, were not used in these sections because of the confounding effect on the variances caused by monthly wind probabilities.

Figure 1-2 graphically illustrates the effects that turnaround time has upon P_L. Observe that after seven days of launch opportunity, the rate of increase in P_L diminishes rapidily with added days in the launch opportunity.

1.7 MINIMUM LAUNCH WINDOW VERSUS PROBABILITY OF LAUNCH

1.7.1 LUNAR LIGHTING REQUIREMENTS. The launch opportunities presented in Reference 3, Direct Ascent Case A, were compared using minimum launch windows of 20 minutes versus 10 minute minimum windows. Only those launch windows meeting the lunar lighting requirements indicated in Paragraph 1.4 were considered.



4K02LV

Figure 1-2. P_L versus Days in Launch Opportunity Showing Effects of Turnaround Time

The results are shown in Table 1-6 for the average P_L for the monthly launch opportunities from mid-1965 through 1968. Considering the case of a 2-day turnaround capability, there is a gain in the average P_L from 0.7893 to 0.8070 by reducing the minimum launch window length to 10 minutes. Potential payload gains, in reducing the minimum launch window, are discussed in detail in Reference 8.

1.8 DIRECT ASCENT VERSUS PARKING ORBIT LAUNCH

1.8.1 MISSION CONDITIONS. All actual launch opportunities for direct and parking orbit ascent missions were examined under conditions previously stated in paragraph 1.5, and with a minimum launch window length of 20 minutes.

A comparison of the average P_L for the direct ascent with that of the parking orbit is shown in Table 1-7. Considering the case of a 2-day turnaround capability, there is a gain in the average P_L from 0.7893 for the direct ascent to 0.8958 for the parking orbit ascent. A gain of 183 acceptable launch windows for the parking orbit over the direct orbit ascent is also indicated.

It is important to note, from Table 1-6, the gain in P_L associated with a decrease in turnaround time. For example, a direct ascent launch with a turnaround time of one day has an average P_L equal to 0.8976 while the parking orbit ascent average P_L for a two day turnaround, involving twice as many launch opportunities and nearly twice as many launch windows, is 0.8958. As shown previously in paragraph 1-5, decreasing the turnaround time in the event of an abort has a stronger effect on the P_L than increasing the number of launch days in a launch opportunity.

1.9 CONCLUSIONS

1.9.1 FACTORS NEEDED FOR A SUCCESSFUL LAUNCH. The probability of a successful launch during any Surveyor launch opportunity is primarily dependent on the turnaround time in the event of an abort. However, with opportunities greater than seven days, there is little gain in decreased turnaround time. See Figure 1-2.

Turnaround time can offset the currently defined advantages of the parking orbit ascent, such as larger launch windows and more launch opportunities. For example, a turnaround time of one day gives the same probability of launch for the average monthly launch opportunity for the single burn mission, as the two day turnaround capability gives to the parking orbit ascent mode.

Weather has been responsible for 24 percent of launch aborts (not including launch rescheduling because of weather). It is more than fortuitous that all weather aborts have occurred during months having a low probability of launch, or, stated otherwise, there have been no recorded weather aborts from May through September at ETR. If at all possible, launches should not be scheduled with monthly launch probabilities of less than 0.5. See Table 1-1.

TABLE 1-6. COMPARISON OF P_L FOR DIRECT ASCENT LAUNCH WITH MINIMUM LAUNCH WINDOW LENGTH OF 20 AND 10 MINUTES

	Launch Window 20 Min.					Launch Window 10 Min.				
Turnaround Time Days	Number of Launch Opportunities	Number of Launch Windows	Maximum P_L	Minimum P_L	Average P_L	Number of Launch Opportunities	Number of Launch Windows	Maximum P_L	Minimum P_L	Average P_L
1	36	161	0.9951	0.5322	0.8976	36	174	0.9951	0.5322	0.9058
2	36	89	0.9521	0.5322	0.7893	36	96	0.9521	0.5322	0.8970
3	36	69	0.8976	0.5322	0.7310	36	74	0.8976	0.5322	0.7541

TABLE 1-7. COMPARISON OF P_L FOR DIRECT ASCENT VERSUS PARKING ORBIT ASCENT LAUNCH. LAUNCH WINDOW $\geq$ 20 MINUTES

	Direct Ascent					Parking Orbit Ascent				
Turnaround Time Days	Number of Launch Opportunities	Number of Launch Windows	Maximum P_L	Minimum P_L	Average P_L	Number of Launch Opportunities	Number of Launch Windows	Maximum P_L	Minimum P_L	Average P_L
1	36	161	0.9951	0.5322	0.8976	63	506	0.9999+	0.5322	0.9449
2	36	89	0.9521	0.5322	0.7893	63	272	0.9977	0.5322	0.8958
3	36	69	0.8976	0.5322	0.7310	63	193	0.9895	0.5322	0.8399

SECTION II

GSE AND FACILITY SYSTEMS LAUNCH-ON-TIME CAPABILITIES

2.1 INTRODUCTION

2.1.1 SCOPE. An analysis of the GSE and Facility Systems on Complex 36A and 36B was performed to determine the capability of each of the systems to meet the contingency hold requirements for a 3σ (.998) probability of launch for the Surveyor direct ascent and parking orbit missions. The hold requirement for individual launch attempts are given in Reference 9.

2.1.2 COMPLEX 36A. The GSE and Facility Systems on Complex 36A provide a total complex/vehicle 3σ probability of launch for the monthly launch opportunity at the opening of the launch window and, utilizing the primary systems for launch, the complex will support a launch window of approximately 93 minutes with a 3σ probability of launch. Using the secondary or backup systems, the complex will support a launch window of 10 minutes with a 3σ probability of launch. The limitations of the complex capability are as follows:

a. All GSE and Facility Systems meet the requirement for a 3σ probability of launch at the opening of the launch window; 126 minutes of reserve time required for range countdown period T-90 to T-0.

b. All GSE and Facility Systems, except the facility GN_2 system (without recharge) and the backup air conditioning supply, meet the requirement for a 3σ probability of launch for the average single-burn launch window; 126 minutes of reserve time required for range countdown plus a 50 minute launch window. The backup air conditioning supply is not considered a major constraint.

c. The facility GN_2 supply system (routine use) is the only major constraint to a 3σ probability of launch for the maximum single-burn window; 126 minutes of reserve time required for range countdown plus an 80 minute launch window.

d. The facility GN_2 supply system is the only major constraint to a 3σ probability of launch for the average two-burn launch window; 126 minutes of reserve time required for range countdown plus a 150 minute launch window.

e. The LH_2, LN_2 air conditioning supply, primary helium supply and facility GN_2 supply systems represent the primary constraints to a 3σ probability of launch for the maximum two-burn launch window; 126 minutes of reserve time required for range countdown plus a 270 minute launch window.

2.1.3 COMPLEX 36B. The GSE and Facility Systems on Complex 36B provide a total complex/vehicle probability of launch of .91 for the monthly launch opportunity. The limitations of the complex capability are as follows:

a. All GSE and Facility Systems, except the LO_2/LN_2 subcooler unit, meet the requirement for a 3σ probability of launch at the opening of the launch window; 126 minutes of reserve time required for range countdown period T-90 to T-0. The LO_2/LN_2 subcooler unit has only a 74 minute hold capability, which is unsatisfactory.

b. The LO_2 system, in addition to the LO_2/LN_2 subcooler, does not support the average single-burn launch window; 126 minutes of reserve time required for the range countdown plus a 50 minute launch window. The usable storage capacity of the LO_2 system would have to be increased to approximately 39,000 gallons to provide this hold capability.

c. The air conditioning GN_2 supply system, in addition to those previously mentioned, does not meet the requirements for the maximum single-burn launch window (206 minutes reserve time) and the average two-burn launch window (276 minutes reserve time). The system usable capacity would have to increased to approximately 155,000 pounds to have this hold capability; existing usable capacity is 146,500 pounds.

d. The LH_2 system, in addition to the LO_2, air conditioning GN_2 and LO_2/LN_2 subcooler systems, does not support the requirements for a 3σ probability of launch for the maximum two-burn launch window; 126 minutes reserve time required for the range countdown plus a 270 minute launch window. The LH_2 system usable capacity would have to be increased to approximately 32,000 gallons to provide this hold capability.

2.2 LAUNCH SUCCESS CRITERIA

2.2.1 GSE AND FACILITY SYSTEMS REQUIREMENTS. To achieve a high probability of launch success of the Atlas/Centaur vehicle during the monthly launch opportunity for the Surveyor Mission, the GSE and Facility Systems require a contingency hold and recycle capability commensurate with predictable countdown delays for each day of launch. The purpose of this analysis is to update the systems capability data for ETR Complex 36A, (Reference 10), and to determine the probability of launch for each of the GSE and Facility Systems on ETR Complex 36B. The launch probability of a system is determined from the available system reserve time (hold capability) and the historical Atlas D-Series flight data from ETR. The probability of launch during the monthly launch opportunity is then established from the number of available launch windows in the monthly opportunity and the complex/vehicle "turn-around" capability (paragraph 1.5).

2.3 DISCUSSION

2.3.1 SYSTEM LAUNCH PERFORMANCE RESERVE. The Launch Performance Reserve (LPR) of a system (Reference 9), is a function of the usable storage capacity, the flow demands on the system during the normal performance of the range countdown, and the flow demands on the system in the event of a launch abort. The usable capacity of a system is established by subtracting the required residual (minimum level allowed) in the storage vessel from the maximum level permitted. A fill tolerance factor is also used to allow for level measurement inaccuracies and to permit loading the cryogenic storage vessels prior to launch day. The flow demands on a system were established by a detailed analysis of the range countdown and abort procedures, a review of the systems parameters document, (Reference 7), and by measured or estimated system flow rates. The system usage figures shown in paragraphs 2.4 and 2.5 of this report are subject to change because of procedural or system design modifications and by a comparison of actual consumption figures during a launch countdown with the estimated values.

2.3.2 SYSTEM PROBABILITY OF LAUNCH (P_L). The probability of launch of a system was established from the calculated available reserve time and the historical data of the Atlas D-Series launches from ETR, Reference 9. The data shows the probability of launch versus reserve time for the range countdown periods T-280 to T-0, T-90 to T-0, and T-10 to T-0 for the following six categories of vehicle launches:

a. All Atlas D-Series launches.

b. All Atlas D-Series launches excluding range and weather holds.

c. Atlas D-Series R&D Vehicle launches.

d. Atlas D-Series Space Vehicle launches.

e. Atlas D-Series Space Vehicle launches excluding range and weather holds.

f. Atlas D-Series Space Vehicle launches excluding planned holds.

Table 2-1 shows the reserve time required for the range countdown period T-90 to T-0 for the six launch vehicle categories with a 3σ probability of launch during the monthly launch opportunity. The range countdown period T-90 to T-0 is used for this analysis because this period includes the more critical operations and time-sequenced events. The existing hold at T-90 minutes is treated as a portion of the range countdown in the calculation of system reserve time and is used to absorb countdown delays prior to T-90 minutes. Table 2-1 shows also the probabilities of single and multiple launch opportunities. For example, if three launch opportunity days are available, a single launch probability of .89 would be required for a 3σ probability of launching during the monthly opportunity. For the Atlas D-Series space launch vehicle category, excluding range and weather holds, the reserve time required is 126 minutes, assuming three launch opportunity days. For two launch opportunity days, 151 minutes of reserve time would be required. The actual system probability of launch is determined from the appropriate table, (Reference 9), after the reserve time has been calculated.

TABLE 2-1. LPR REQUIRED FOR 3σ LAUNCH PROBABILITY FOR MONTHLY LAUNCH OPPORTUNITY

Launches per Opportunity	P_L Per Launch	All Atlas D-Series	All Atlas D-Series Excluding Range & Weather	Atlas D-Series R&D Launches	Atlas D-Series Space Launches	Atlas D-Series Space Launches Excluding Range & Weather	Atlas D-Series Space Launches Excluding Planned Holds
1	.998(3σ)	304	268	367	208	210	206
2	.96	209	184	248	151	151	148
3	.89	169	148	198	126	126	123
4	.79	137	121	159	107	106	103

The launch vehicle category used to determine the system probability of launch for this analysis was the Atlas D-Series space launches excluding range and weather holds. This category was selected for the following reasons:

a. There have been too few Atlas/Centaur launches to establish, with reasonable confidence, the reserve time required for a high probability of launch.

b. The Atlas D-Series space launch data includes the Atlas/Centaur, Atlas/Agena, and the Atlas/Mercury vehicles. These vehicles represent the operational Atlas/Centaur complexity with regard to vehicle and GSE systems as well as the range requirements for launch success.

c. The Atlas D-Series space vehicle launch data reflects improved launch capability because of the experience and learning gained during the R&D phase of flights.

d. The range and weather hold data was omitted to establish the system probability of launch at the opening of the launch window. For this analysis, the launch window will be used to absorb the range and weather holds.

2.3.3 SYSTEM PARAMETERS AND STUDY GROUND RULES. The analysis of the GSE and Facility Systems was performed to establish the following system parameters for ETR Complex 36B and to update the data for ETR Complex 36A, Reference 10:

a. The minimum reserve time available using existing procedure and operating requirements.

b. The probability of launch for the system at the opening of the launch window for a single launch opportunity day.

c. The probability of launch of the system during the monthly launch opportunity.

d. The reserve time available in excess of that required for a probability of launch of 3σ. The excess reserve time represents the portion of the launch window that can be used and maintain a probability of launch at 3σ.

A review of these system parameters will identify the systems constraining the total complex/vehicle probability of launch and will define the procedural or design modifications required to achieve a probability of launch of 3σ.

The ground rules used in the development of this analysis are as follows:

a. A monthly launch opportunity is assumed to consist of a minimum of five launch windows and three launch opportunities, i.e., a turnaround capability in the event of an abort of two days.

b. A probability of launch of 3σ for the monthly launch opportunity is required at the opening of the launch window.

c. The average and maximum single-burn launch windows are 50 and 80 minutes, respectively.

d. The average and maximum two-burn launch windows are 150 and 270 minutes, respectively.

2.4 COMPLEX 36A GSE AND FACILITY SYSTEMS

2.4.1 SYSTEMS RESERVE ANALYSIS. The Complex 36A GSE and Facility Systems data previously presented, (Reference 1), have been updated with current system operating requirements and system modifications. The data is summarized in Table 2-2. The detailed data calculations and general system schematics are shown in Appendix A. The schematics are presented only for basic orientation of the differences between Complex 36A and 36B and to show system capacities, usages and flow demands. Table 2-2 provides the following pertinent information for each system:

a. Column A identifies the system investigated and, where applicable, its prime function.

b. Column B denotes the system schematic number, Appendix A, from which the system usages can be identified.

c. Column C lists the usable capacity of the system. The usable capacity assumes maximum level at the start of the range countdown.

d. Column D shows the total demand on the system during the range countdown. For this analysis, the existing 60-minute scheduled hold at T-90 minutes is included as part of the range countdown.

e. Column E indicates the required demand on the system in the event of an aborted launch. The value shown represents the maximum requirement for an abort occurring after T-3 seconds.

f. Column F reports the maximum usage rate of the system.

g. Column G denotes the minimum reserve time available for the system. This figure is derived by dividing the system capacity available for holding by the maximum usage rate of the system. For example, the LH_2 Systems' capacity available for holding is 11,200 gallons and the maximum usage rate is 45 gpm. Therefore, the minimum reserve time available is:

$$\text{Reserve Time} = \frac{11,200 \text{ gallons}}{45 \text{ gpm}} = 249 \text{ minutes}$$

h. Column H shows the single launch day probability of launch, based on the reserve time required for the time period T-90 minutes to T-0, at the opening of the launch window.

i. Column I shows the system probability of launch for the monthly launch opportunity.

j. Column J reports the reserve time available in excess of that required for a 3σ probability of launch for the monthly launch opportunity. The excess reserve time represents the launch window that can be met by each system with a 3σ probability of launch.

Only one of the GSE and Facility Systems at Complex 36A does not have the usable capacity required for a 3σ probability of launch at the opening of the launch window, the Atlas thrust section air conditioning system. This system is activated at T-5 minutes for the purpose of providing an inert atmosphere in the engine compartment prior to engine ignition. The system can be secured any time after activation in the event of a countdown delay and, with the 14 minute reserve time available, can support a minimum of three recycles. This capability is adequate to support the vehicle launch with a high probability of success.

/

TABLE 2-2. ETR COMPLEX 36A GSE & FACILITY

System	Schematic Figure No.	Usable Capacity	Range Count-Down Usage
(A)	(B)	(C)	(D)
LO_2 Transfer System	A-1	51,200 gallons	28,945 gallons
LO_2 Storage Tank Helium Pressurization Supply	A-1	1,392 lb	1,089 lb
LH_2 Transfer System	A-2	25,000 gallons	13,800 gallons
LHe System	A-3	900 gallons	160 gallons
LN_2 System, Facility	A-4	19,000 gallons	3,621 gallons
LN_2 System, Air Conditioning	A-5	177,000 lb	35,370 lb
Helium System, 3000 psig Primary Supply	A-6	42,800 scf	12,030 scf
Helium System, 6000 psig Emergency Supply	A-6	38,400 scf	22,220 scf (3)
Helium System, 6000 psig Insulation Panel Purges	A-7	6,000 lb	1,625 lb
GN_2 System, 2400 psig Routine Use Using Facility Recharger	A-8	6,710 lb (4)	5,700 lb
Routine Use Without (5) Facility Recharger	A-8	6,710 lb	3,150 lb
GN_2 System, 2400 psig Backup Air Conditioning Supply	A-5	146,500 lb	35,370 lb
GN_2 System, 8000 psig Hold-down & Release	A-8	280 lb	55 lb
GN_2 System, Atlas Thrust Section	A-5	1,530 lb	400 lb

(1) The excess reserve time is that portion of the launch window that can be met with a 3

(2) Figure assumes launch abort after T-3 seconds.

(3) For 2 burn missions the range countdown usage is approximately 19,450 scf.

(4) Usable capacity figure indicates static storage only. Use of the facility recharger wi which includes 570 minutes reserve time of the facility LN_2 system.

(5) In the event the facility recharger is inoperable for the range countdown, the air cond shown reflect routine GN_2 usage excluding the LN_2 flow demands.

(6) The Atlas Thrust Section air conditioner is activated at T - 5 minutes. The time indic

2

SYSTEMS SUMMARY LAUNCH PERFORMANCE RESERVE ANALYSIS

Abort Usage	Maximum Usage Rate	Minimum Reserve Time Available, Minutes	Probability of Launch P_L Single Launch	P_L MLO	Excess Reserve Time, Minutes (1)
(E)	(F)	(G)	(H)	(I)	(J)
0	53 gpm	420	.999	.999	294
0	0	∞	.999	.999	∞
0	45 gpm	249	.999	.999	123
0	5 gpm	148	.954	.999	22
200 gallons	26.7 gpm	570	.999	.999	444
60,870 lb (2)	368.5 lb/min	219	.999	.999	93
12,000 scf	50 scfm	375	.999	.999	249
8,400 scf	0	∞	.999	.999	∞
640 lb	280 lb/hour	800	.999	.999	674
4,075 lb	21.7 lb/min	879	.999	.999	753
2,250 lb	7.8 lb/min	161	.984	.999	35
60,870 lb (2)	368.5 lb/min	136	.923	.999	10
0	0	∞	.999	.999	∞
0	80 lb/min	14 (6)	< .50	< .50	0

r probability of launch.

h a recharge capacity of 80 lb/min exceeds the demand flow and provides a reserve of 879 minutes

tioning backup system will be utilized in lieu of the LN_2 air conditioning system. The figures

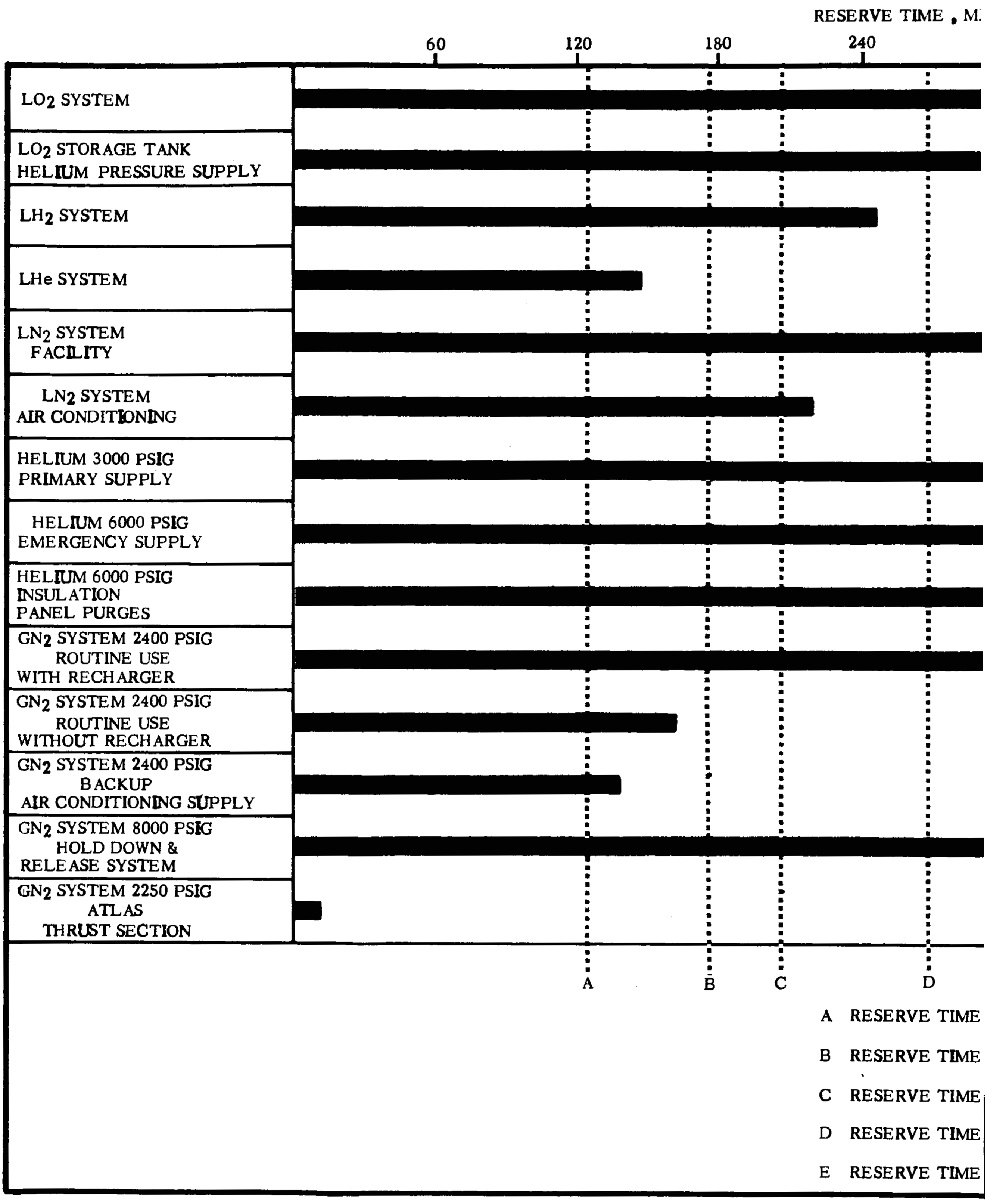
ated allows a minimum of 3 recycle operations.

2.4.2 SYSTEMS CAPABILITY TO SUPPORT SINGLE AND TWO-BURN LAUNCH WINDOWS. Figure 2-1 summarizes the data of Column G of Table 2-2. The available reserve time of each of the GSE and Facility Systems at Complex 36A is shown in relation to the reserve time required to support and utilize the single and two-burn mission launch windows with a 3σ probability of launch. Lines B and C represent the reserve time required for the average and maximum single-burn launch windows. Lines D and E represent the reserve time required for the average and maximum two-burn launch windows, respectively. Line A is the reserve time required for a 3σ probability of launch at the opening of the launch window.

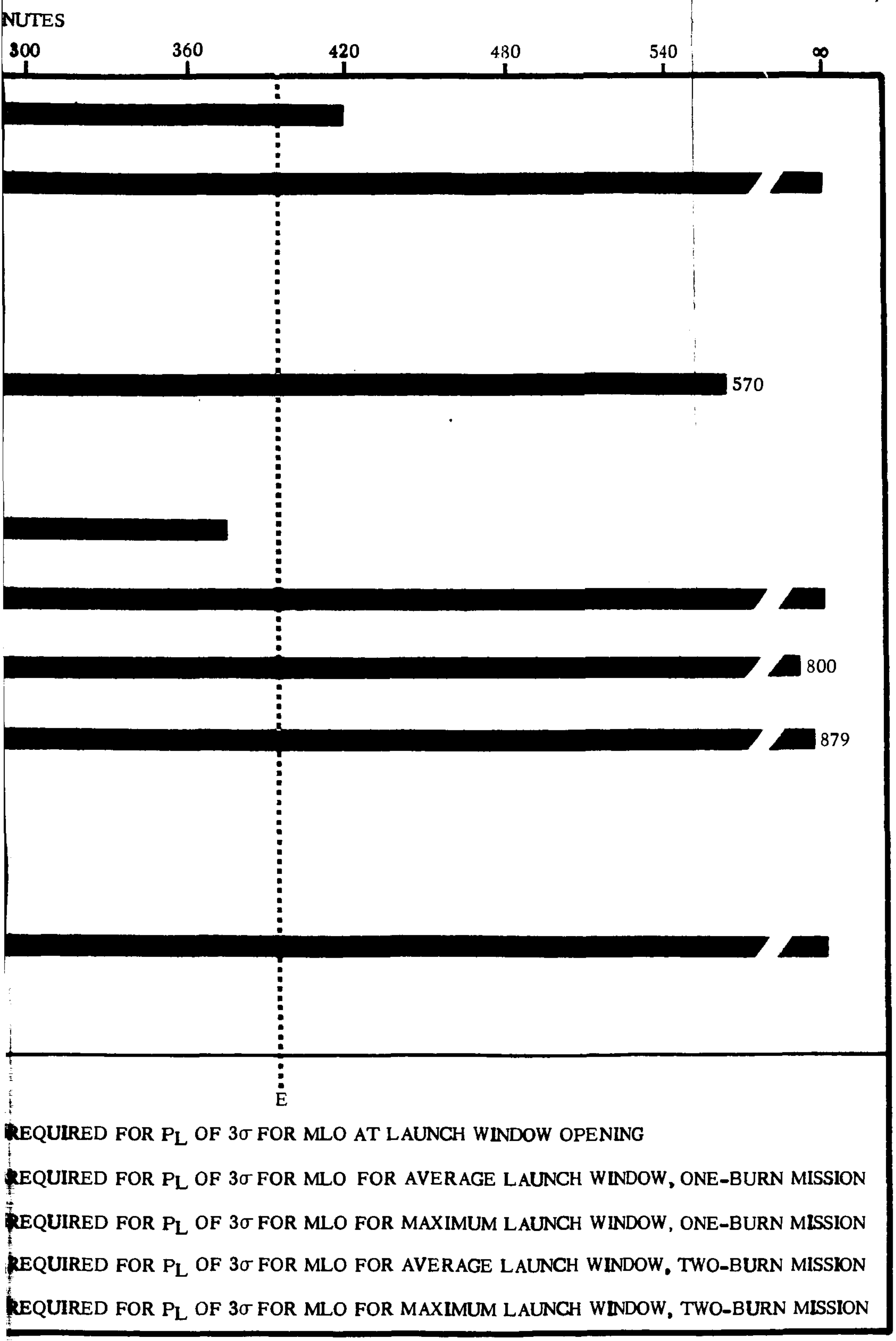
Four systems will not support the average single-burn launch window. They are the Atlas thrust section air conditioning system, the GN_2 system (routine use), the air conditioning backup GN_2 system, and the LHe system. As previously discussed, the Atlas thrust section air conditioning system can be secured at any time after activation and has the capability of a minimum of three recycles. This capability is considered adequate, and does not constrain the complex/vehicle probability of success. The 148 minute reserve time shown for the LHe system assumes continuous flow. This system, like the Atlas thrust section air conditioning system, can be secured in the event of a delay after activation, and can be reactivated at any time as long as temperature and time restrictions are met. This operating capability will extend the available reserve time to the maximum required. Therefore, this system does not appear to constrain the complex/vehicle probability of success.

The facility GN_2 (without recharger) and the air conditioning backup GN_2 supply systems are a backup mode of operation and are used only in the event that the facility recharger malfunctions. The system constraints, therefore, do not appear to be critical. If it becomes likely, however, that the situation would arise, and the maximum reserve time is essential, then the requirement to maintain GN_2 flow to the interstage adapter until the engine standby purges are reinstalled should be investigated. Securing the GN_2 flow at T+60 minutes instead of T+240 minutes will increase the air conditioning system reserve time to approximately 241 minutes, which exceeds the maximum single-burn launch window requirements. Consideration could then be given to transferring one of the 700 ft^3 GN_2 bottles in the backup air conditioning supply, (Figure A-8), to the facility GN_2 storage. This transfer would increase the facility GN_2 system reserve time to approximately 710 minutes and would reduce the air conditioning supply reserve time to approximately 225 minutes. The available reserve time for both systems will then exceed the requirements for the maximum single-burn launch window.

All GSE and Facility Systems, except those previously discussed, support the maximum single-burn launch window requirements.


RESERVE TIME , M
60
120
180
240
LO2 SYSTEM
LO2 STORAGE TANK HELIUM PRESSURE SUPPLY
LH2 SYSTEM
LHe SYSTEM
LN2 SYSTEM FACILITY
LN2 SYSTEM AIR CONDITIONING
HELIUM 3000 PSIG PRIMARY SUPPLY
HELIUM 6000 PSIG EMERGENCY SUPPLY
HELIUM 6000 PSIG INSULATION PANEL PURGES
GN2 SYSTEM 2400 PSIG ROUTINE USE WITH RECHARGER
GN2 SYSTEM 2400 PSIG ROUTINE USE WITHOUT RECHARGER
GN2 SYSTEM 2400 PSIG BACKUP AIR CONDITIONING SUPPLY
GN2 SYSTEM 8000 PSIG HOLD DOWN & RELEASE SYSTEM
GN2 SYSTEM 2250 PSIG ATLAS THRUST SECTION
A
B
C
D
A RESERVE TIME
B RESERVE TIME
C RESERVE TIME
D RESERVE TIME
E RESERVE TIME

2



4K03LT

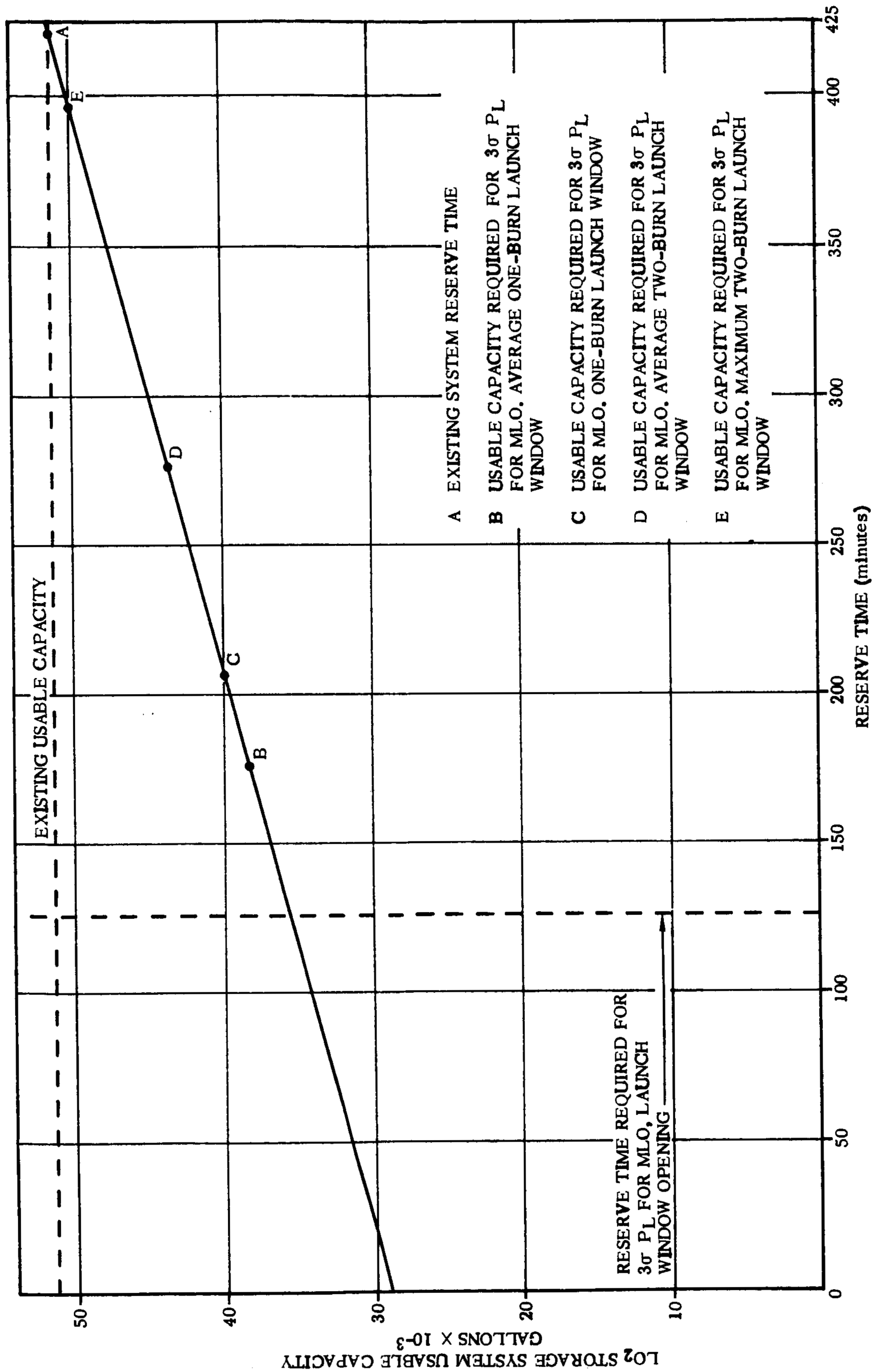
Figure 2-1. Summary Available Reserve Time, GSE & Facility Systems, for Vehicles AC-6 & on, Complex 36A

For the two-burn mission, two systems in addition to those previously mentioned do not have the reserve time available to support the average and maximum two-burn launch windows, the LH_2 and the LN_2 air conditioning systems. By topping the LH_2 storage tank to maximum capacity on the day of launch, i.e., deleting the fill tolerance allowance, the LH_2 system will have adequate capacity to support the average two-burn launch window. Deleting the requirement to supply GN_2 to interstage adapter until the engine standby purges are reinstalled will increase the LN_2 air conditioning system reserve time to approximately 324 minutes. This reserve time is more than adequate to support the average two-burn launch window. Without major system modifications, however, neither the LH_2 nor LN_2 air conditioning systems will support the maximum two-burn launch window. The LHe and Atlas thrust section air conditioning systems are considered adequate because of the capability to secure their operation in the event of an extended delay. The facility GN_2 supply (without facility recharger) and air conditioning backup GN_2 system constraints are not considered critical because these systems would only be used in an emergency; i.e., a malfunction of the facility recharger unit.

2.4.3 SYSTEM CAPACITY VERSUS HOLD CAPABILITY. Figures 2-2 through 2-9 show usable capacity versus reserve time of the primary systems which affect complex/vehicle hold capability. The relationship of usable capacity to the average and maximum single and two-burn launch windows is also shown, points B, C, D and E. Point A is indicative of the existing system reserve time. For example, to obtain a 3σ probability of launch for the average two-burn launch window, the LH_2 usable capacity would have to be increased to approximately 26,500 gallons, point D, Figure 2-3. Conversely, the figures show the available reserve time for storage capacities other than maximum. For example, if the LO_2 storage capacity is 40,000 gallons instead of the maximum 51,000 gallons, the available reserve time is approximately 210 minutes, Figure 2-2. This capacity would be adequate to support the maximum single-burn launch window, point C, Figure 2-2.

2.5 COMPLEX 36B GSE AND FACILITY SYSTEMS

2.5.1 SYSTEMS RESERVE ANALYSIS. Complex 36B GSE and Facility Systems data which define the launch support capability are summarized in Table 2-3. The data shown reflects current system operating requirements and design. The detailed system data calculations and general system schematics are given in Appendix B. The schematics are presented for basic orientation of the differences between Complex 36A and 36B, and to show system capacities, usages and flow demands.



4K04LT

Figure 2-2. Complex 36A LO_2 System Capacity versus Hold Capability

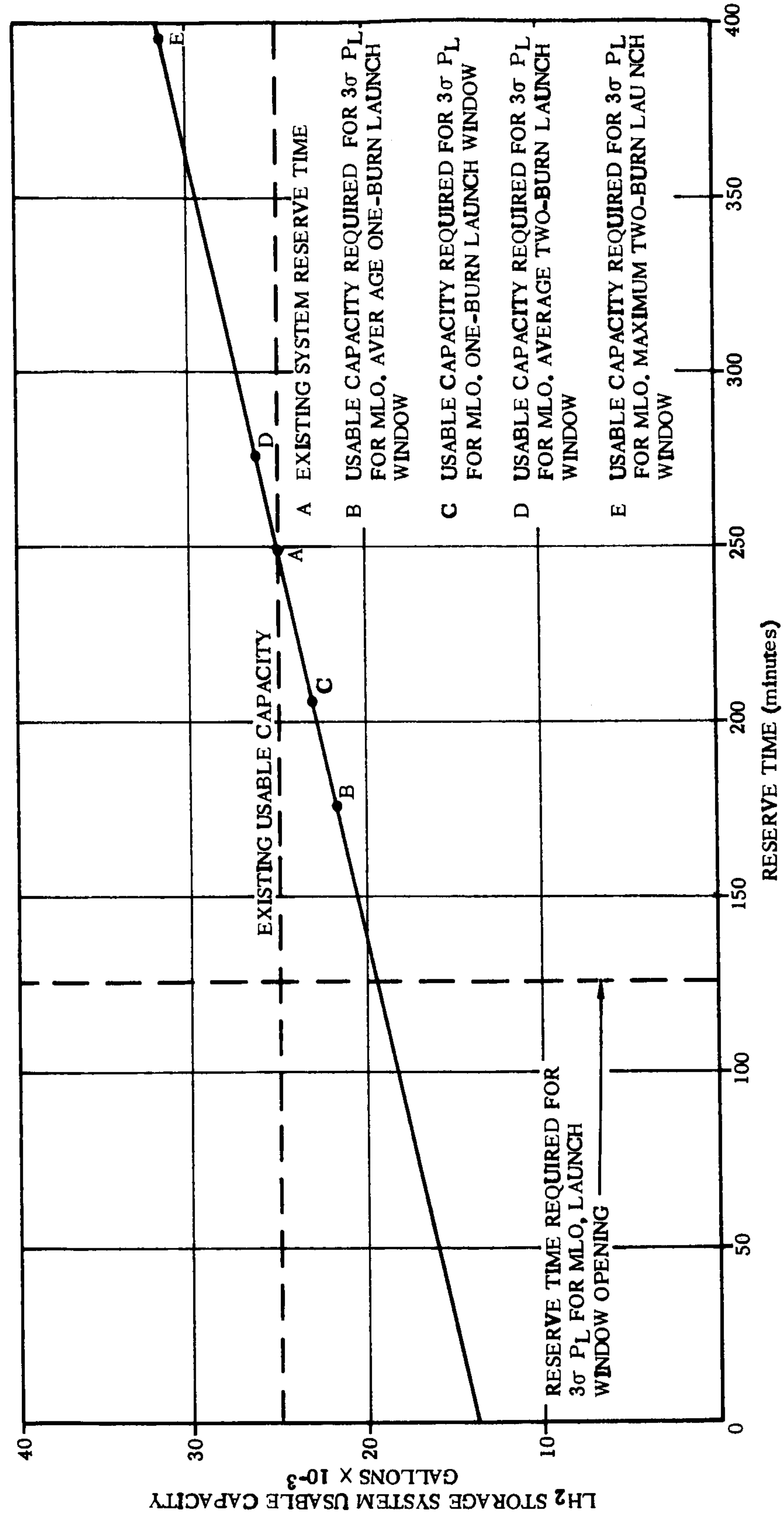


Figure 2-3. Complex 36A LH_2 System Capacity versus Hold Capability

4K05LT

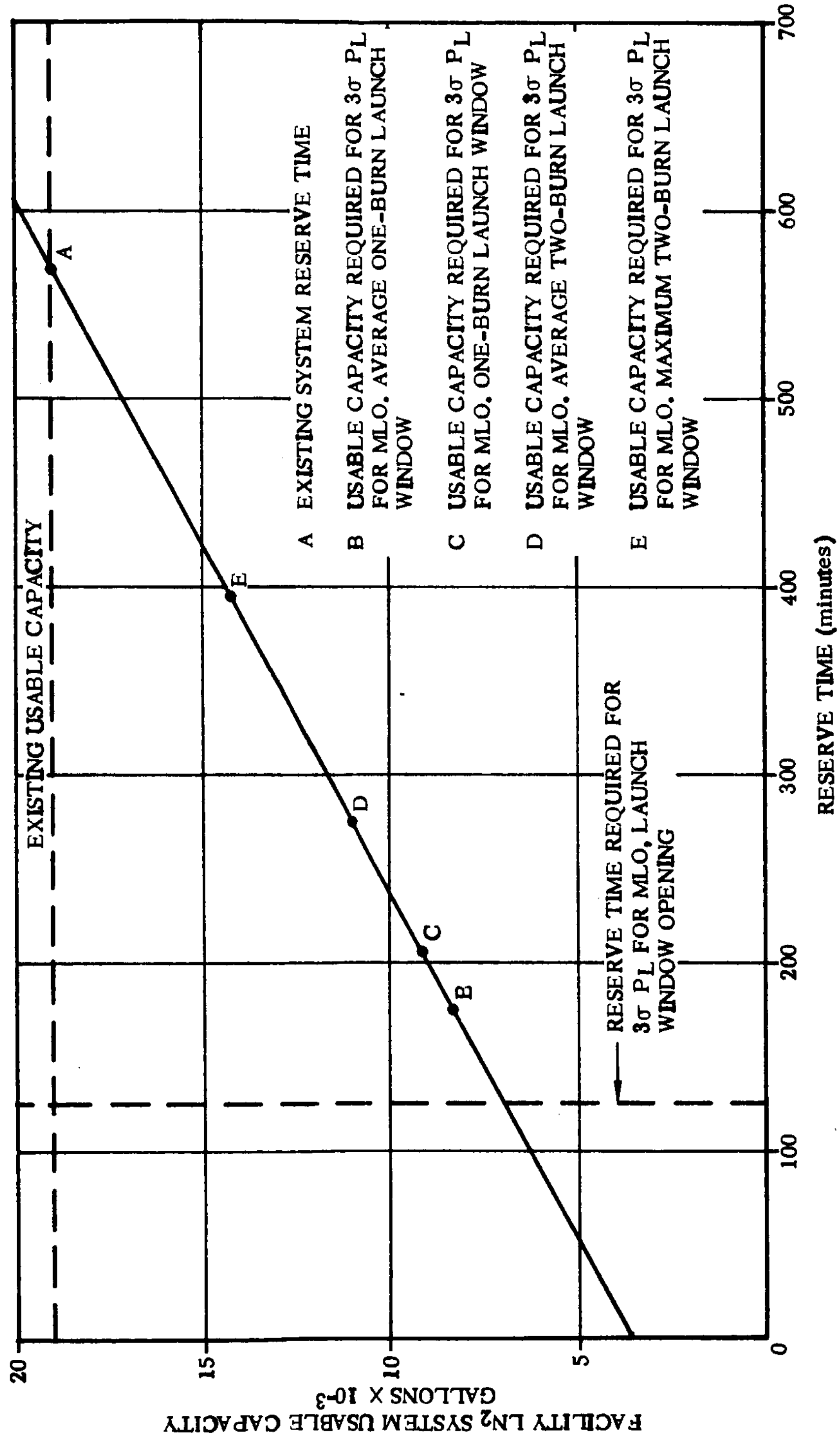


Figure 2-4. Complex 36A, Facility LN_2 System Capacity versus Hold Capability

4K06LT

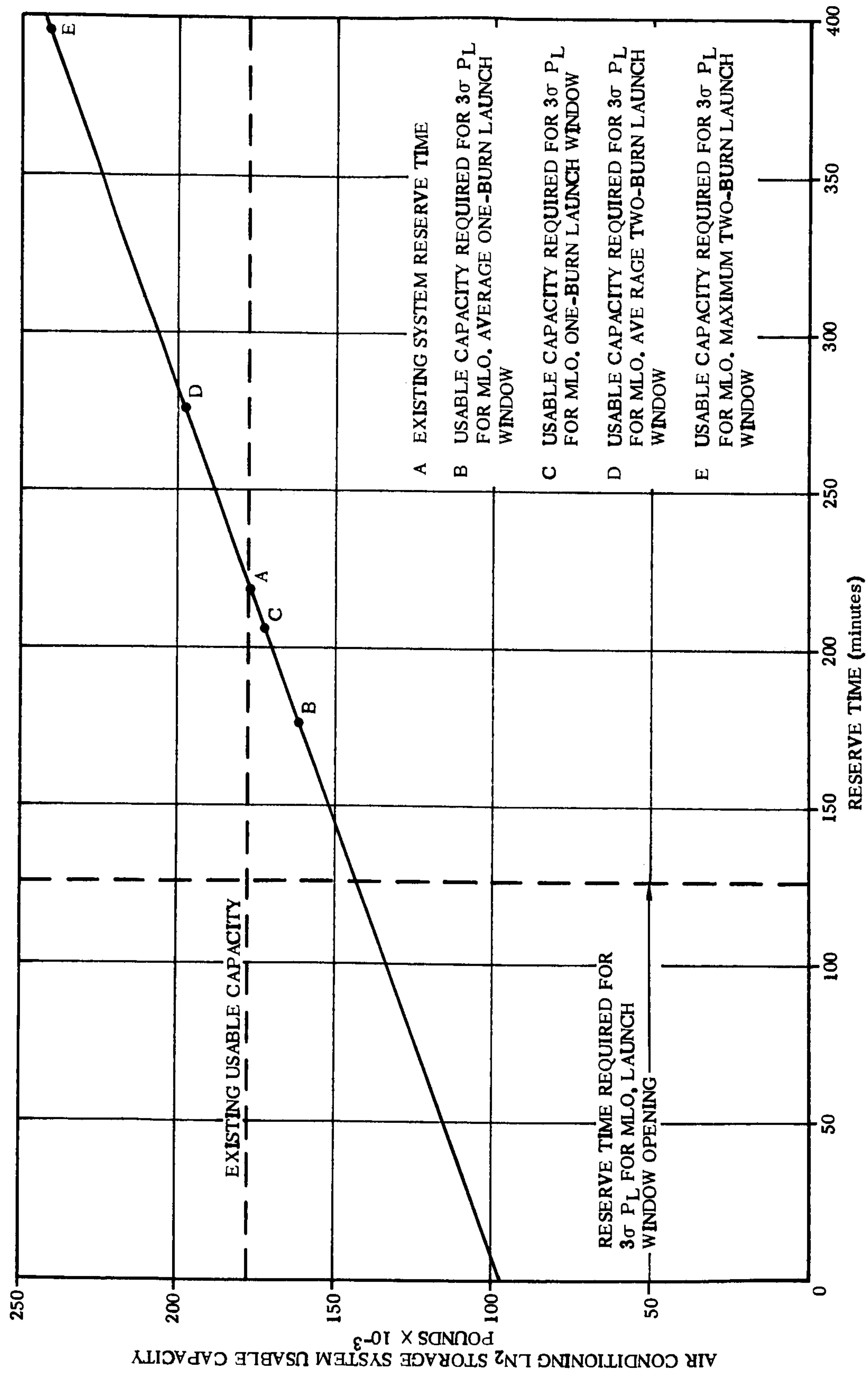


Figure 2-5. Complex 36A, Air Conditioning LN_2 System Capacity versus Hold Capability

4K07LT

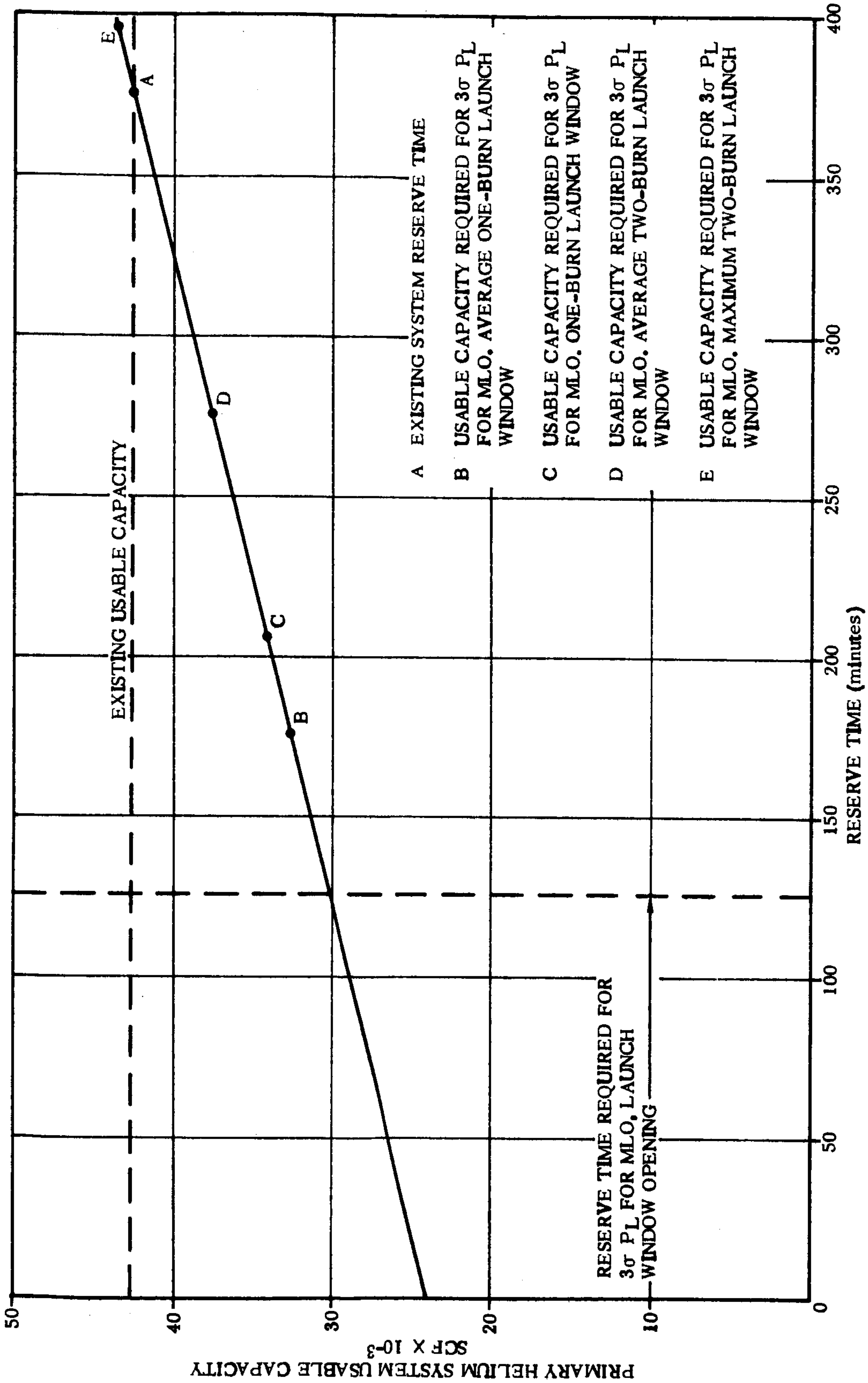
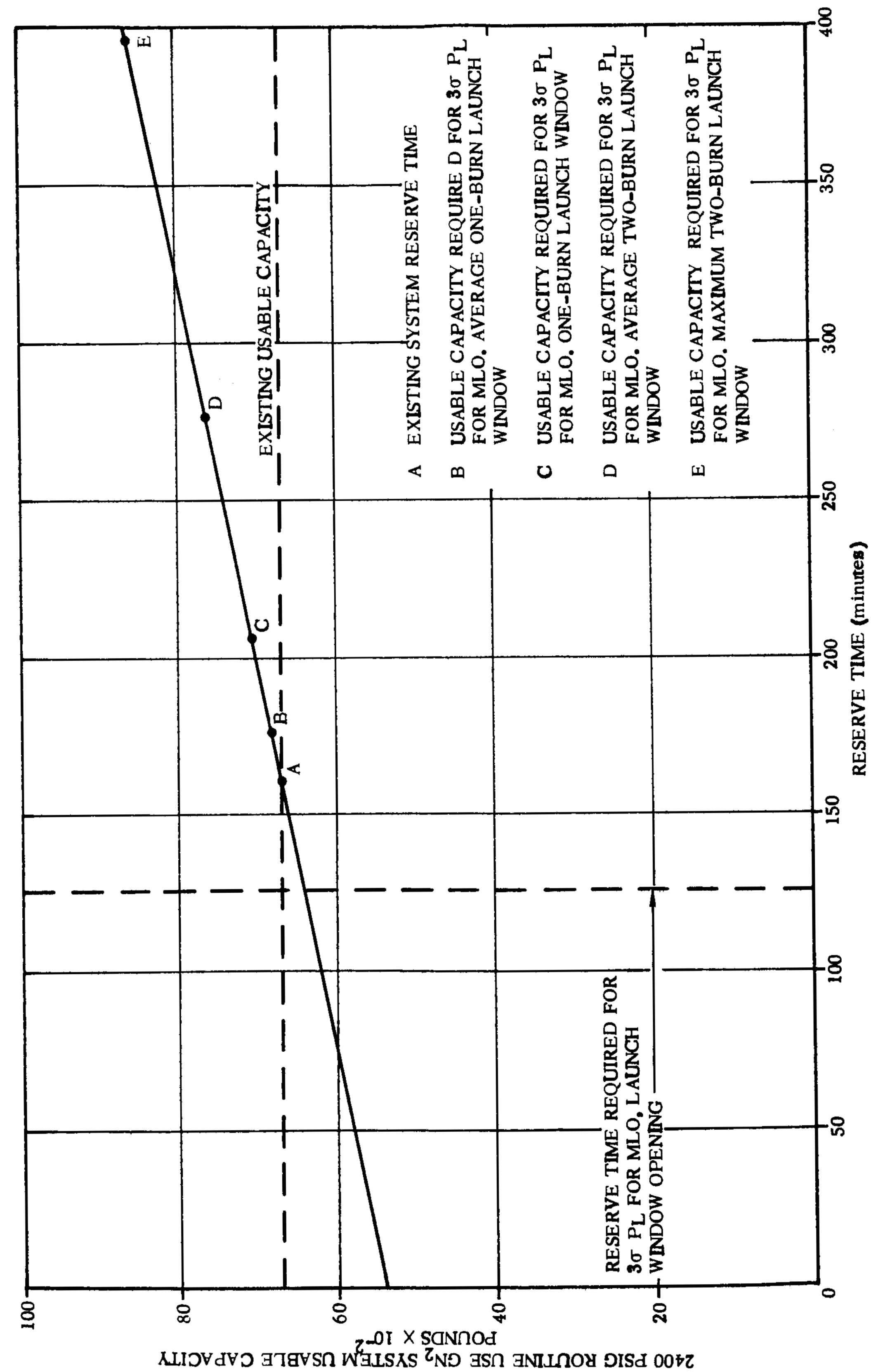


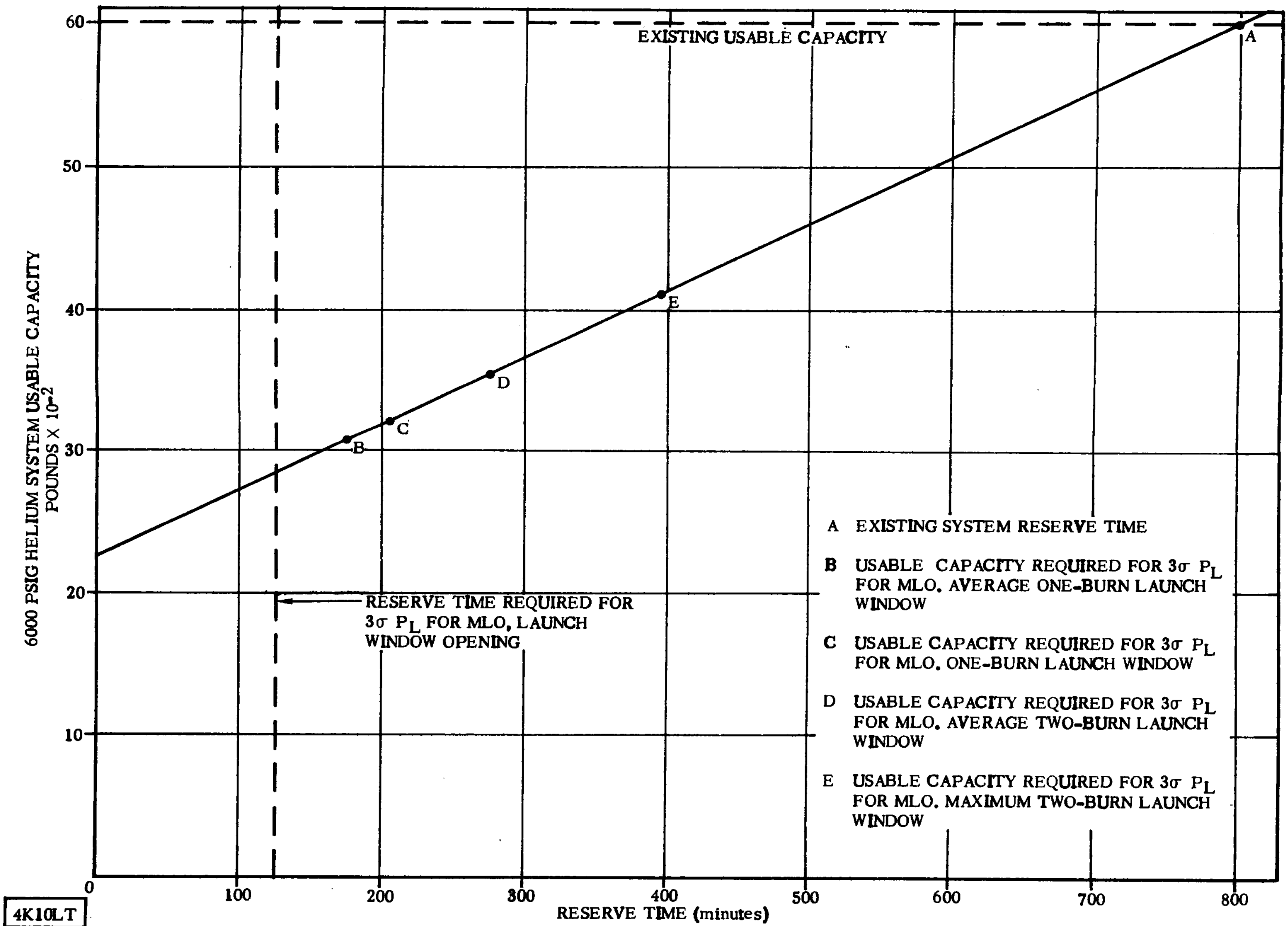
Figure 2-6. Complex 36A, 3000 PSIG Helium System, Primary Supply

4K08LT



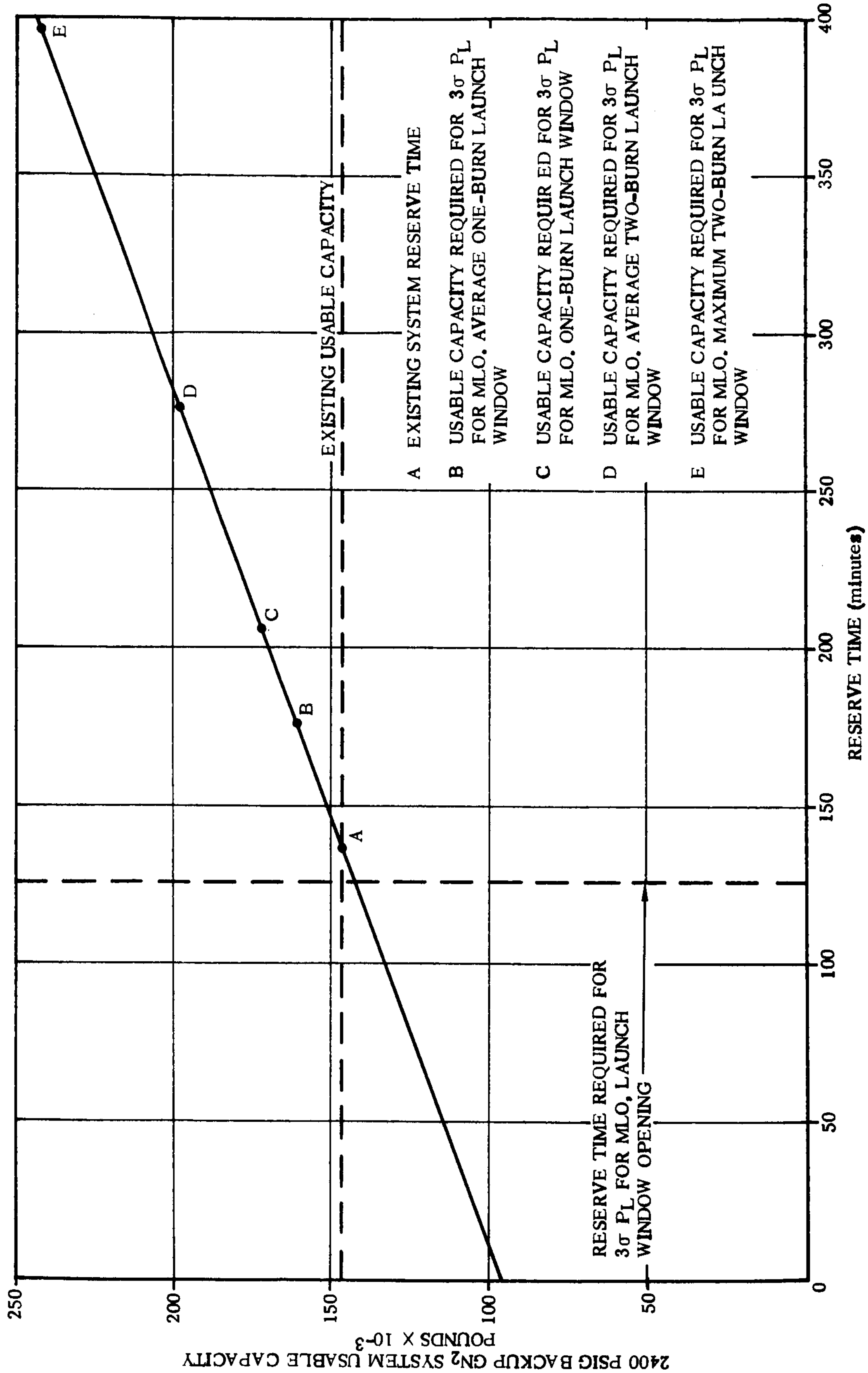
4K09LT

Figure 2-7. Complex 36A, Routine Use GN_2 System Capacity versus Hold Capability without Recharger



4K10LT

Figure 2-8. Complex 36A, 6000 PSIG Helium System, Insulation Panel Purges



4K11LT

Figure 2-9. Complex 36A, Backup Air Conditioning GN_2 System Capacity versus Hold Capability

/

TABLE 2-3. ETR COMPLEX 36B GSE & FACILI

System	Schematic Figure No.	Usable Capacity	Range Count-Down Usage
A	B	C	D
LO_2 System	B-1	36,500 gallons	29,475 gallons
LH_2 System	B-2	25,000 gallons	13,800 gallons
LHe System	B-3	900 gallons	160 gallons
LN_2 System	B-4	25,000 gallons	2,875 gallons
LO_2/LN_2 Subcooler	B-4	1,204 gallons	228 gallons
LN_2 Storage Tank GN_2 Supply	B-4	5,110 lb	3,540 lb
Helium System, 6000 psig Vehicle Pressurization	B-5	92,800 scf	35,110 scf (2)
Helium System, 6000 psig Insulation Panel Purges	B-6	6,000 lb	1,625 lb
GN_2 System, 6000 psig (Routine Use)	B-7	9,600 lb	3,234 lb
GN_2 System, 2400 psig Air Conditioning Supply	B-8	146,500 lb	34,040 lb
GN_2 System, 8000 psig Hold-Down & Release	B-7	150 lb	12 lb

(1) The excess reserve time is that portion of the launch window that can be met with a
(2) For 2 burn missions, the range countdown usage is approximately 35,190 scf and th
(3) The available reserve time is referenced to a 4 hour purge of the interstage adapter

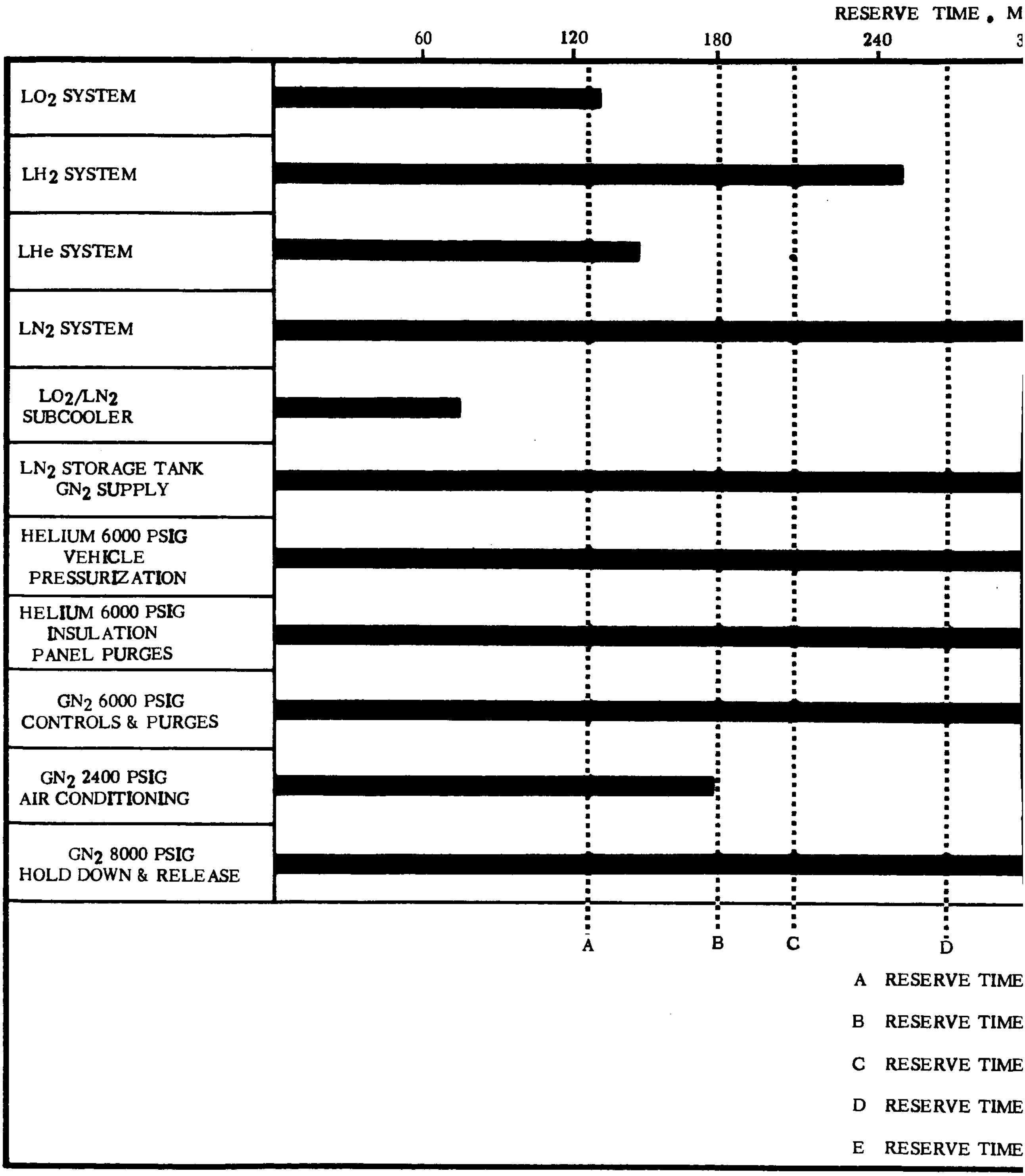
The LO_2/LN_2 subcooler is the only GSE or Facility System that does not have the usable capacity required for a 3σ probability of launch at the opening of the launch window. This unit subcools the LO_2 during Atlas and Centaur LO_2 topping and has a usable capacity of 1204 gallons of LN_2. With a usage rate of approximately 13 gpm, the available reserve time is 74 minutes. This reserve time represents an unsatisfactory system probability of launch of approximately .55. A design modification similar to that provided on Complex 36A is required, i.e., the capability for remote level sensing and fill. This modification would increase the unit hold capability to the required maximum, and would decrease the hold capability of the LN_2 storage system to approximately 950 minutes. This capacity is more than adequate to support the Atlas/Centaur Vehicle single and two-burn launch missions.

2.5.2 SYSTEM CAPABILITY TO SUPPORT SINGLE AND TWO-BURN LAUNCH WINDOWS. Figure 2-10 summarizes the data of Column G of Table 2-3. The available reserve time of each of the GSE and Facility System at Complex 36B is shown in relation to the reserve time required to support the single and two-burn launch windows. Lines B and C represent the reserve time required for the average and maximum single-burn launch windows, respectively. Lines D and E represent the reserve time required for the average and maximum two-burn launch windows, respectively. Line A is the reserve time required for a 3σ probability of launch at the opening of the launch window.

Four systems do not support the average and maximum single-burn launch windows, the LO_2 system, the LHe system, the air conditioning GN_2 system and the LO_2/LN_2 subcooler. The LO_2/LN_2 subcooler hold capability is unsatisfactory and will require a design modification. The LHe system has the capability to be secured and reactivated in the event of a countdown delay, therefore, the system capacity is considered adequate to support the Surveyor Mission launches.

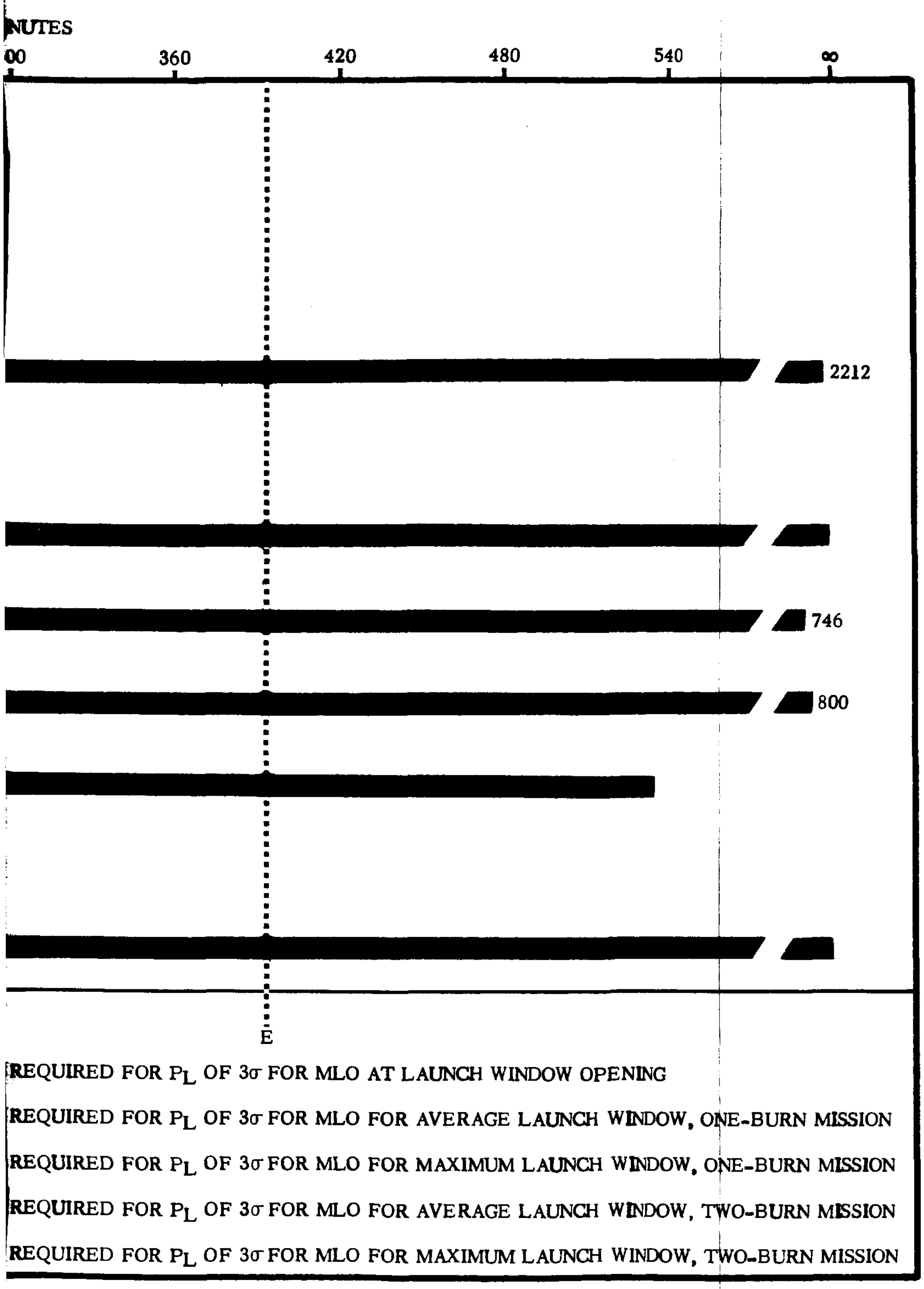
The LO_2 system will require an increase in usable storage capacity of approximately 4,000 gallons (total of 40,500 gallons) to provide the required hold capability for the average and maximum single-burn launch windows. The air conditioning GN_2 supply has adequate capacity for the average single-burn launch window. However, for the maximum window, the capacity would have to be increased to approximately 155,000 pounds to provide the required hold capability, existing usable capacity is 146,500 pounds. Deleting the requirement to maintain GN_2 flow to the interstage adapter until engine standby purges are reinstalled, in the event of an abort after T-3 seconds, will increase the system hold capability by approximately 82 minutes. This added capability would be adequate to support the single-burn mission requirements.

The LH_2 system, in addition to the systems previously discussed, does not support the average and maximum two-burn launch windows. Topping the LH_2 storage to maximum capacity on the day of launch will provide adequate capacity to support the average two-burn window. However, to support the maximum window, the LH_2 storage usable capacity would have to be increased to approximately 32,000 gallons.



RESERVE TIME, M
60
120
180
240
LO2 SYSTEM
LH2 SYSTEM
LHe SYSTEM
LN2 SYSTEM
LO2/LN2 SUBCOOLER
LN2 STORAGE TANK GN2 SUPPLY
HELIUM 6000 PSIG VEHICLE PRESSURIZATION
HELIUM 6000 PSIG INSULATION PANEL PURGES
GN2 6000 PSIG CONTROLS & PURGES
GN2 2400 PSIG AIR CONDITIONING
GN2 8000 PSIG HOLD DOWN & RELEASE
A
B
C
D
A RESERVE TIME
B RESERVE TIME
C RESERVE TIME
D RESERVE TIME
E RESERVE TIME

2



4K12LT

Figure 2-10. Summary of available Reserve Time, GSE & Facility System for Vehicles AC-6 & on, Complex 36B

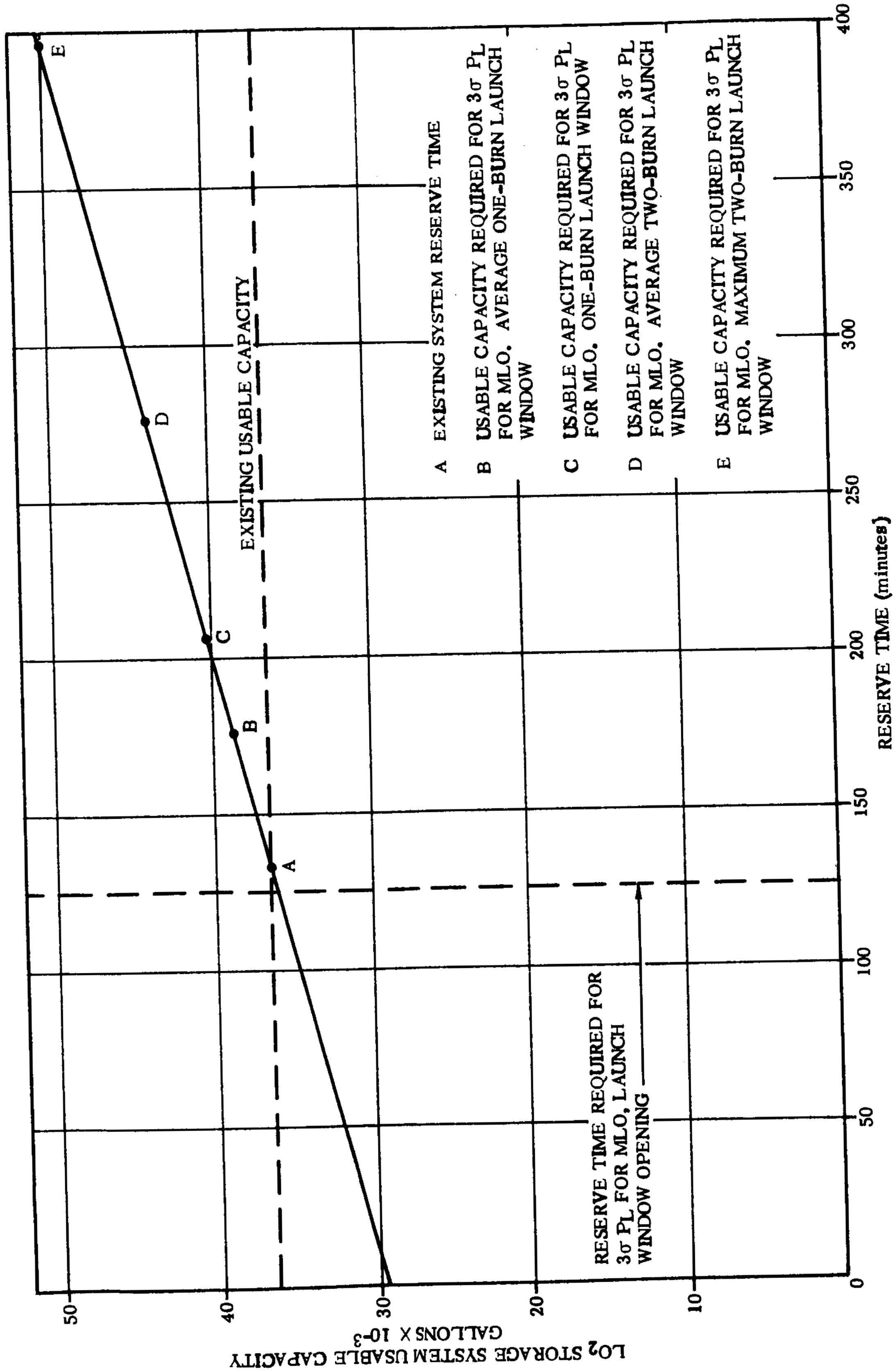
2.5.3 SYSTEM CAPACITY VERSUS HOLD CAPABILITY. Figures 2-11 through 2-18 show the usable capacity versus reserve time for the primary systems affecting complex/vehicle hold capability. The relationship of the usable capacity to the average and maximum single and two-burn launch windows is also shown, points B, C, D and E. Point A is indicative of the existing system reserve time. For example, to obtain a 3σ probability of launch for the average two-burn launch window, the LH_2 storage usable capacity would have to be increased to approximately 26,500 gallons, point D, Figure 2-12. Conversely, the figures show the available reserve time for storage capacities other than maximum. For example, if the helium pressurization system capacity is 70,000 scf instead of 92,800 scf, the reserve time available would be 290 minutes, Figure 2-15. This capacity would be adequate to support the average two-burn launch window, point D, Figure 2-15.

2.6 CONCLUSIONS

2.6.1 CONSTRAINTS ON LAUNCH CAPABILITY. Table 2-4 summarizes the conclusions of the analysis. The systems that constrain the complex/vehicle launch capability are shown in relation to the launch requirements for a 3σ probability of success. As the table shows, the primary constraint is the LO_2/LN_2 subcooler unit on Complex 36B. This deficiency should be resolved. The remaining system constraints should be resolved as soon as firm program requirements are defined.

TABLE 2-4. ETR COMPLEX 36 - SYSTEM CONSTRAINTS TO A 3σ PROBABILITY OF LAUNCH

System	Launch Window Opening	Launch Capability Constraints			
		Single-Burn		Two-Burn	
		Av Launch Window	Max Launch Window	Av Launch Window	Max Launch Window
Complex 36A:					
Facility GN_2 (W/O Recharger)		X	X	X	X
LH_2 System					X
LN_2 Air Conditioning				X	X
Complex 36B:					
LO_2/LN_2 Subcooler	X	X	X	X	X
LO_2 System		X	X	X	X
Air Conditioning GN_2			X	X	X
LH_2 System					X



4K13LT

Figure 2-11. Complex 36B, LO_2 System Capacity versus Hold Capability

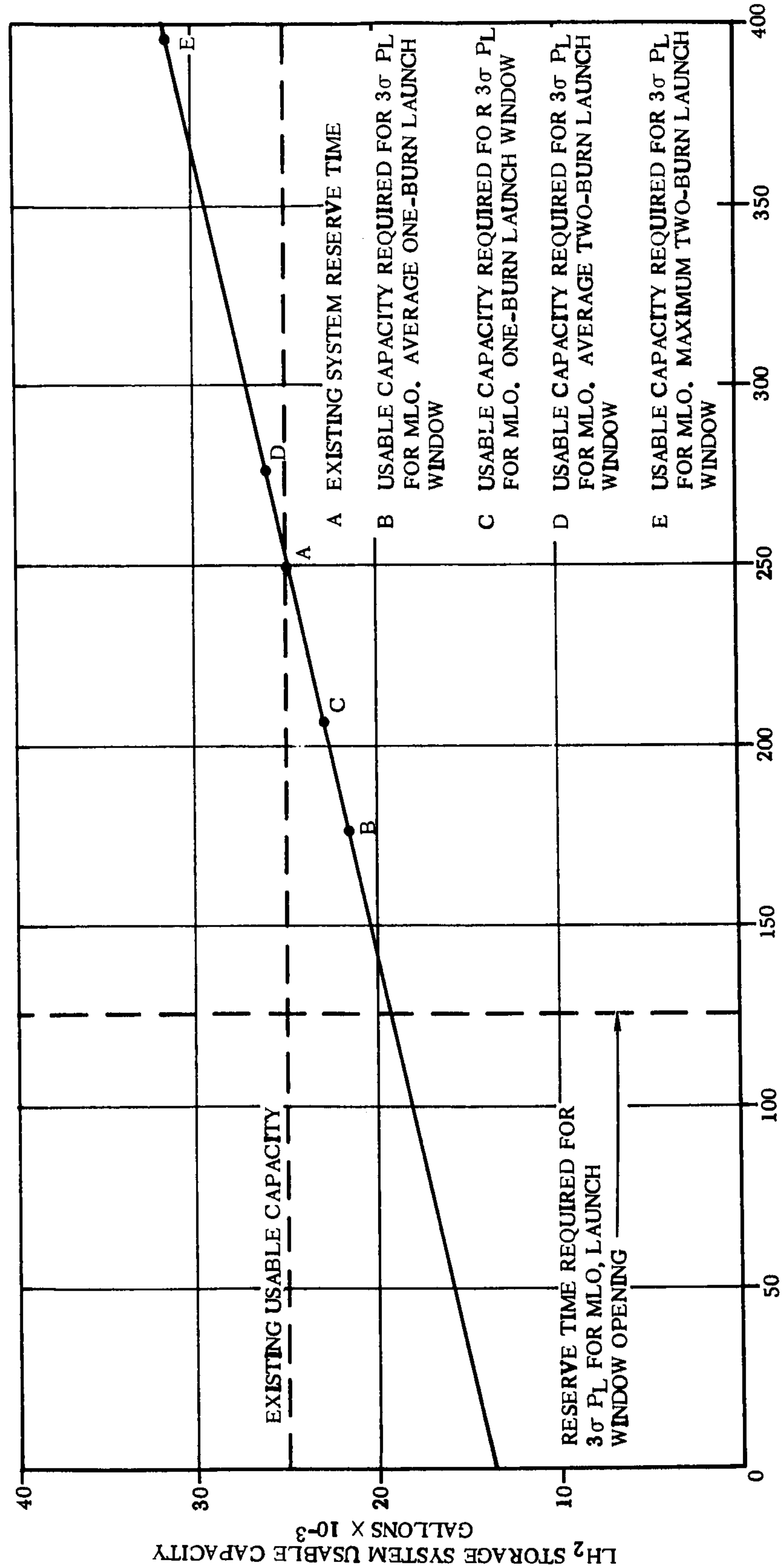


Figure 2-12. Complex 36B, LH_2 System Capacity versus Hold Capability

4K14LT

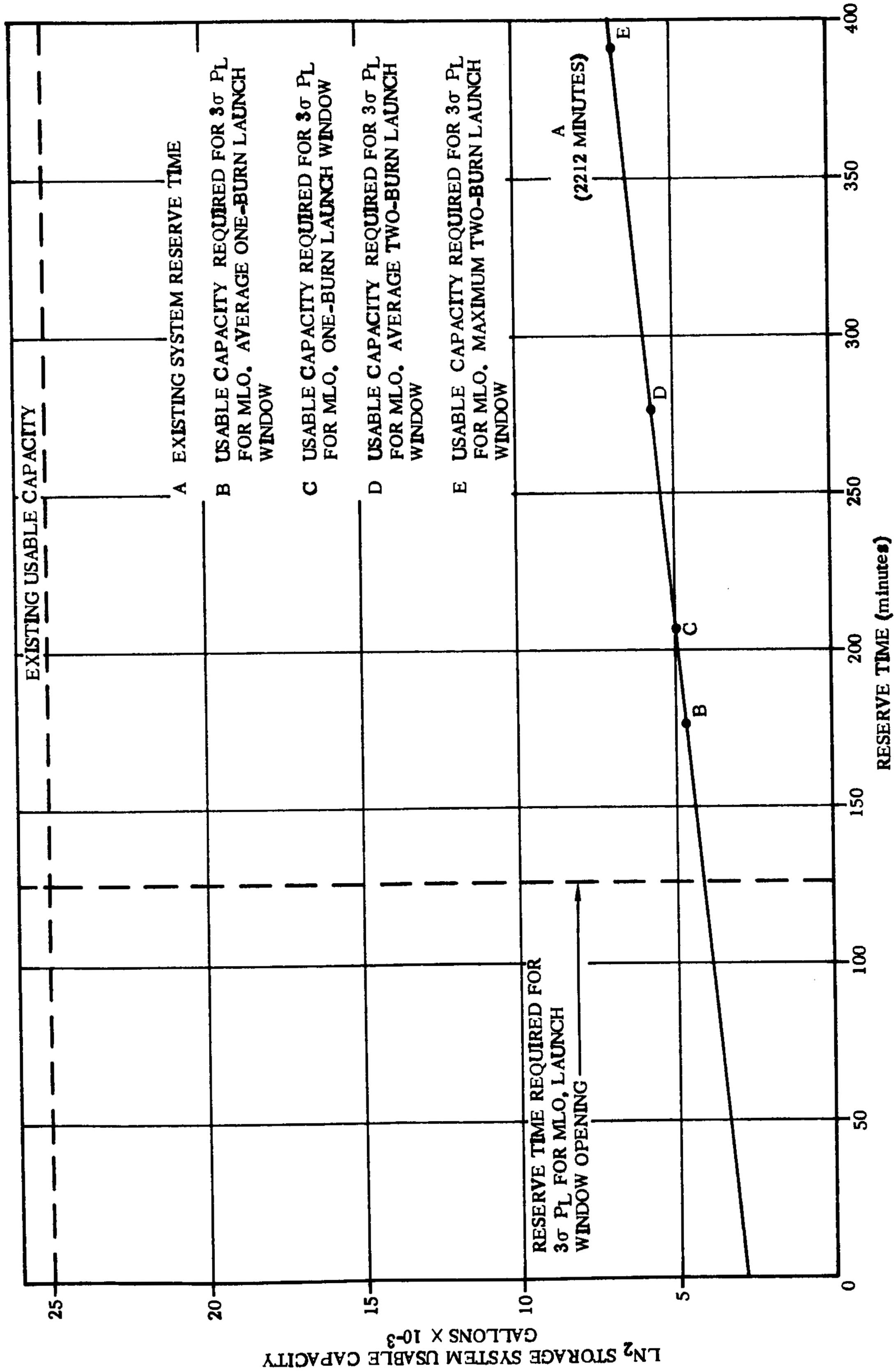
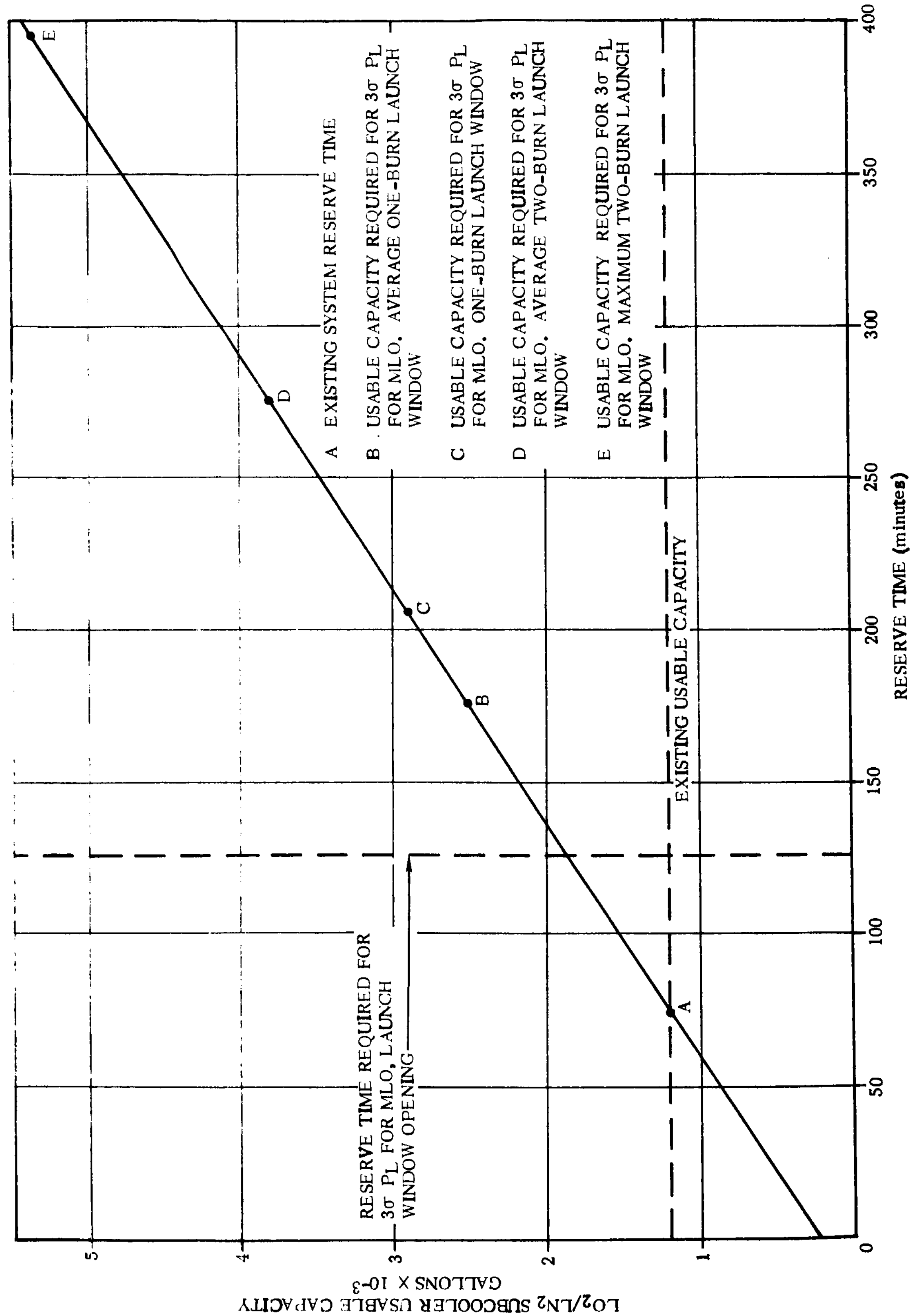


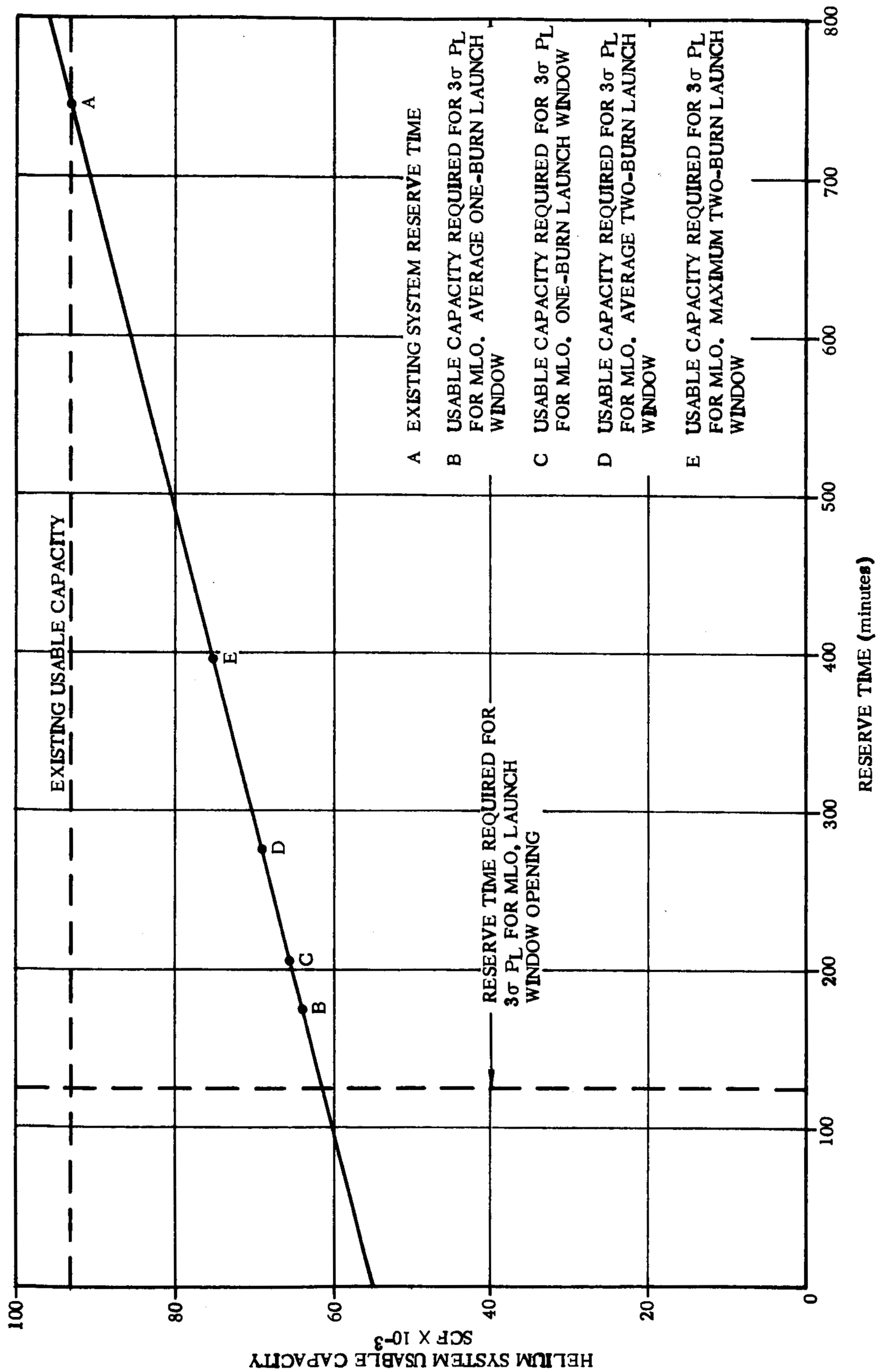
Figure 2-13. Complex 36B, LN_2 System Capacity versus Hold Capability

4K15LT



4K16LT

Figure 2-14. Complex 36B, LO_2/LN_2 Subcooler Capacity versus Hold Capability



4K17LT

Figure 2-15. Complex 36B, 6000 PSIG Helium Pressurization System Capacity versus Hold Capability

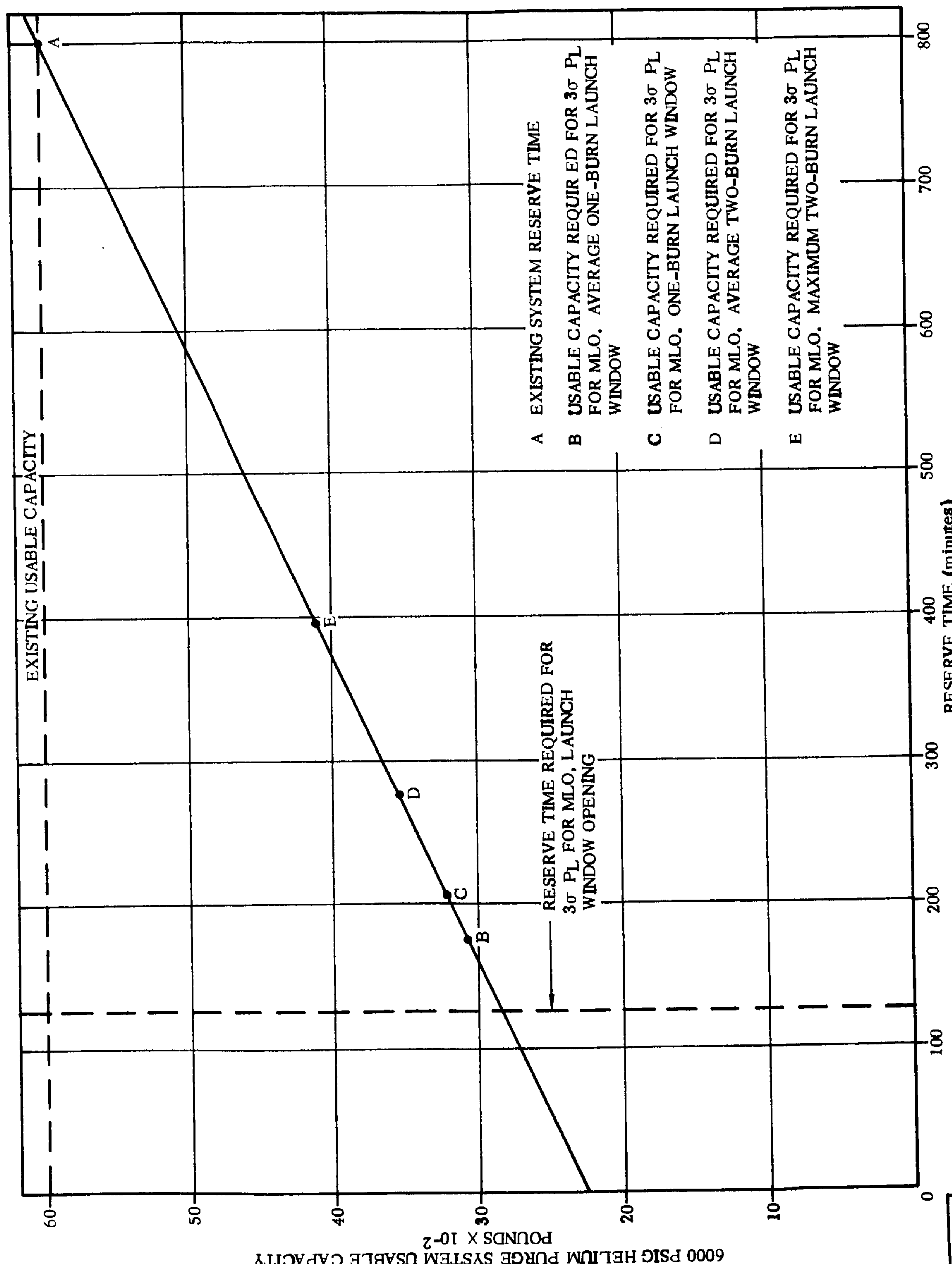


Figure 2-16. Complex 36B, 6000 PSIG Helium Purge System, Capacity versus Hold Capability

4K18LT

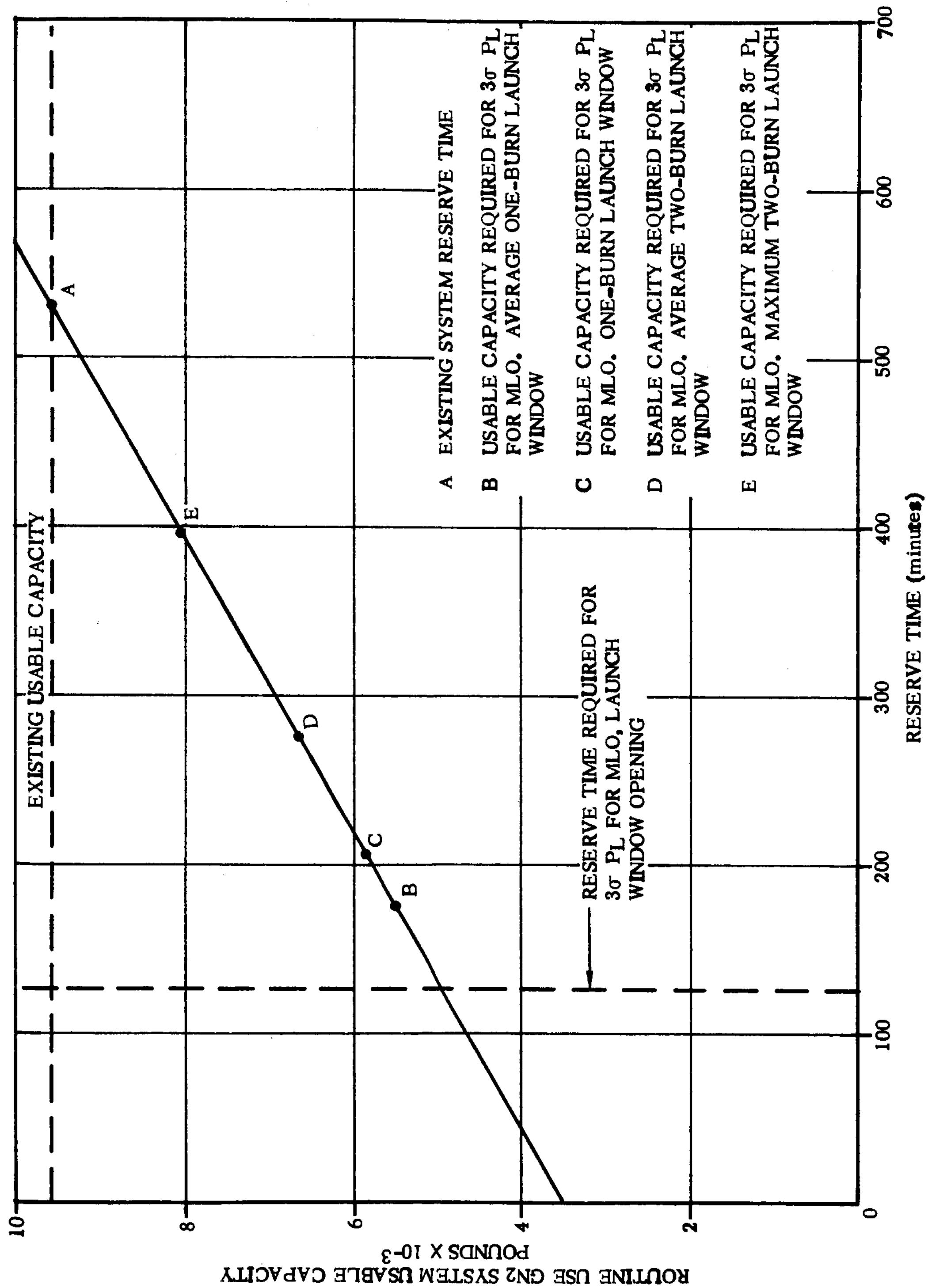
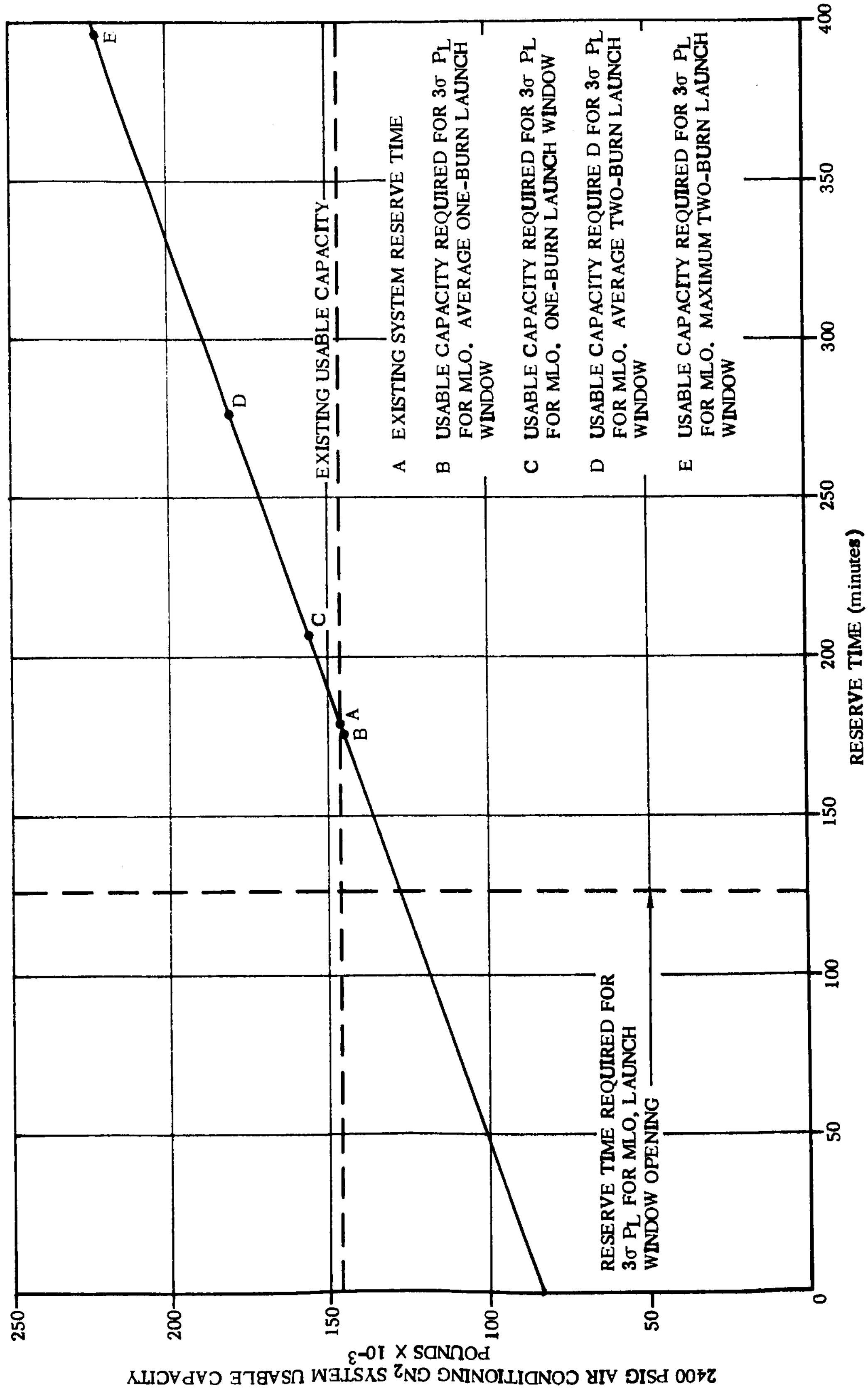


Figure 2-17. Complex 36B, 6000 PSIG GN_2, Routine Use, System Capacity versus Hold Capability

4K19LT



4K20LT

Figure 2-18. Complex 36B, Air Conditioning GN_2 System Capacity versus Hold Capability

SECTION III

COMBINED SYSTEMS TEST STAND

3.1 INTRODUCTION

3.1.1 PURPOSE. The main purpose of the Combined Systems Test (CST) Stand Pre-Operational Verification Test Program was to demonstrate the capability of the facility to perform integrated systems checkout. The T-21 Spacecraft and the AC-7 Launch Vehicle were used to demonstrate this capability. The checkout verified the hardware and procedures of CST as well as the electrical and mechanical interface of the spacecraft and launch vehicle.

3.1.2 CST TEST PROGRAM OBJECTIVES. Most of the basic objectives of the CST Test Program were met. These included the following:

a. Demonstrated the mechanical compatibility of the Centaur and spacecraft, interstage adapter, and Centaur interfaces

b. Verified the adequacy of the space vehicle launch preparations, handling and countdown procedures

c. Verified the compatibility of the CST facility with the Surveyor spacecraft.

The following basic objectives were not met fully due to test equipment wiring problems and component out-of-tolerance malfunctions:

a. Demonstrated the compatibility of the space vehicle electrical systems and GSE during the simulated second stage retromaneuver, including spacecraft operation

b. Demonstrated the RF and electrical compatibility of the space vehicle inflight configuration.

It is anticipated that prior to the retest of the Atlas/Centaur vehicle for the CST site selloff demonstration, the GSE wiring problems and component out-of-tolerance malfunctions will be corrected.

3.2 CST WORK PLAN T-21/AC-7

The CST Model Work Plan is based upon a 40 M-day period, with 20 days alloted for GSE modification and 20 days for system test and evaluation, in accordance with the May LOT Report (Reference 11). The actual time span for the T-21/AC-7 CST work plan was 55 days. Engineering design changes and part shortages increased the GSE modification and checkout time beyond the model work plan 20 day period.

Most of the GSE installations encountered problems which resulted in the model work plan differing from the actual work schedule. The anticipated GSE modification time was to start on work day 42 and end on day 20. However, the GSE systems were undergoing modification and checkout starting at work day 55 and ending on work day 16, just prior to the planned arrival of the T-21 Spacecraft. It is anticipated that since the GSE is now in "operational configuration" the 40 day modification period from day 55 to day 16 would not be repeated and the more realistic period of 20 working days would be followed. The spacecraft arrival date slipped two days from day 15 to day 13. This caused minor changes in the model work plan schedule. In general the actual work plan followed the model work plan quite closely during the last 15 days. The spacecraft was shipped to ETR on schedule at the end of day 1.

3.2.1 CST WORK PLAN CHANGES. During the modification and test sequence several changes were made to the CST work plan. The need for rescheduled and deleted tasks was anticipated since this was the first time the spacecraft and the Atlas/Centaur launch vehicle were checked out in the CST facility. The changes to the CST work plan are described below.

a. Rescheduled tasks:

(1) Landline Installation Checkout - Procedure Number AY65-0531-001-13. Section C of this procedure was rescheduled to ensure proper landline cable operation just prior to the start of combined acceptance testing.

(2) Telemetry System Checkout - AY65-0531-002-13. Sections C and D of this procedure were rescheduled to ensure proper operation of the GD/C telemetry system just prior just prior to the start of combined acceptance testing.

(3) Remove Insulation Panels - AY65-0539-004-13. In the model work plan, the insulation panels were to be removed from the Centaur vehicle prior to the erection of the T-21 Spacecraft. However, it was decided that the insulation panels should remain on during the combined acceptance test to ensure system compatibility and more closely simulate inflight conditions. The insulation panel removal task was rescheduled to be performed after the T-21 Spacecraft had been demated from Centaur.

b. Deleted tasks:

(1) Electrical Power Checkout, AY65-0535-050-13. This procedure checks out the 400 cycle power control and distribution system. Included as part of this system is the 7 volt DC and 28 volt DC power supply system. This procedure was deleted since these systems were already in operational configuration as a result of the CST facility activation.

(2) Propulsion System Checkout, AY65-0535-056-13. This procedure checks out the ground side of the first and second stage engine control system. It was not run during the CST testing since the propulsion system was in operational configuration as a result of the CST facility activation.

(3) Launcher Simulator Checkout, AY65-0535-064-13. This procedure verifies that all of the ground handling equipment used for Atlas and Centaur are on site and in good condition ready for use. The procedure was incorporated into the Test Conductors Monitor System checkout, AY65-0535-067-13.

(4) Inertial Guidance System GSE Checkout, AY65-0535-061-13. This procedure was cancelled and never written. However, the current planning is that it will be written prior to the arrival of the next spacecraft. The factory checkout procedure was utilized to check out the GSE prior to the start of formal CST operations.

(5) Vehicle Power Checkout, AY65-0535-053-13. This procedure validates the first and second stage vehicle power ground control system and was accomplished when the vehicle power GSE was validated.

(6) T-21 Interaction Test, Hughes Aircraft Company Procedure. This test was deleted due to a schedule problem. The verification of the electrical and mechanical performance of the omnidirectional antennas, spacecraft landing legs, solar panel and planar array positioner, Surveyor/Centaur separation switches and the T.V. survey cameras were checked during the combined acceptance test.

3.3 CST SELLOFF

The CST selloff demonstration using the AC-7 launch vehicle started on June 28. The tests will be limited to the Atlas/Centaur vehicle and its GSE since the T-21 Spacecraft will not be available. The demonstration will follow the same sequence and procedures used during the T-21/AC-7 integrated systems checkout. The planned completion date is July 27 when the Centaur stage is shipped to ETR.

3.4 CST SCHEDULE

3.4.1 PLANNED OPERATIONS. The present planned operations for CST is to cycle all of the remaining launch vehicles, AC-8 through AC-15, through the facility for test and evaluation. These include all of the basic Atlas/Centaur/Surveyor vehicles of the following configurations:

a. 1-Burn R&D

b. 2-Burn R&D

c. 1-Burn Operational

d. 2-Burn Operational

e. Dual Capability - Operational.

The sequence of launch vehicles through CST is such that the flight mission changes with each successive vehicle, from a 1-burn mission to a 2-burn mission. This results in the necessity to perform a mission peculiar modification task for each vehicle and supporting CST GSE. Prior to the delivery of the AC-8 vehicle to CST, the GSE will have been modified to handle the basic 1- and 2-burn missions, but will not include mission peculiar instrumentation and landline changes. The model work plan allocates 40 working-days to accomplish the GSE modification, and Atlas/Centaur/Spacecraft testing. A schedule time period of greater than 40 working-days will allow slack time for unexpected contingencies. A schedule of less than 40 working-days can cause a constraint in the test program.

The master schedule for the AC-8, 2-burn mission, allocates 25 working-days for CST modification and test. While this period is not adequate for the CST operation, a schedule slack time of 41 working-days is available for GSE modification prior to the start of testing.

For the AC-10, 1-burn mission, 30 working-days are available for GSE modification and system testing. Due to schedule slack time an additional 10 working-days are available, making a total of 40 working-days.

AC-9 is a 2-burn mission vehicle. The time allocated for CST testing is 21 working-days. The available slack time is only 3 working-days. Based upon the 40 working-day model work plan, 24 working-days are not adequate to perform GSE modification and systems testing. This will require rescheduling the AC-9 test program.

AC-11, 1-burn mission, has allocated 35 working-days for CST operations with an additional 36 working-day slack period available, if required.

Launch Vehicles AC-12 through AC-15 are allocated the full 40 working-day period for CST operations. Adequate slack time is available, if required.

3.5 CST - MODIFICATION CENTER

Increasing effort is being applied to minimize or even eliminate the necessity for launch vehicle modification at ETR. The ideal situation would have a "clean" vehicle, one with all CIC changes incorporated, provided by the factory to CST and then delivered to ETR (Task 1, T.D. 12, LOT). This ideal situation is not likely to be attained because of the continuing stream of component changes and late parts which must be incorporated into the vehicles before launch.

3.5.1 LIMITATIONS. At present some modification to the Atlas and Centaur vehicles and CST GSE are being performed at the CST facility. These are post factory Form DD-250 changes to the flight hardware which must be incorporated prior to CST testing. Most of these changes involve flight component replacement or modification, wiring changes and instrumentation changes. Some of these changes require GSE revisions to insure proper checkout and test evaluation. These changes can be easily performed in the CST facility, however, any changes to the major systems, structure, pressurization system, engine system, etc., is now performed in the factory because of the specialized tools and test stands. Further modifications at CST is, at present, limited by the following items:

a. Physical limitation of CST to perform certain modifications

b. Accessibility of the launch vehicles for modification purposes

c. Time availability to perform modifications.

The accessibility of the Atlas and Centaur for modification is increased in the CST facility compared to the factory. The interstage adapter and Centaur vehicle can be erected in the vertical position in the CST test tower. Access platforms that fit around the vehicle are located at many levels making the task of modification quite easy. Access to the Atlas is improved over that in the factory.

The availability of time to incorporate modifications into the launch vehicle at CST is dependent upon the slack time built into the Master Schedule. Vehicles AC-8 through AC-10 have a minimum of slack time available for modification for changes other than those which must be incorporated for test purposes. Vehicles AC-11 through AC-15 have a sufficiently large amount of slack time which can be used to incorporate all of the post factory Form DD-250 changes.

In summary, it is possible and advantageous to use the CST facility as a modification center for small component changes, wiring revisions, instrumentation and landline changes and other revisions which do not require the use of large specialized tools or large complex systems to validate the change.

SECTION IV

REFERENCES

1. Empirical Analysis of Daily Peak Surface Wind at Cape Kennedy, Florida for Project Apollo, NASA MSFC TMX-53116, 27 August 1964.

2. Effect of Pitch Program Variations on Launch Availability of Atlas/Centaur, AC-7 to AC-15, (Phase I), GD/A-DDE64-045, 28 December 1964.

3. Surveyor Launch Opportunities for Mid-1965 Through 1968, GD/C-BTD65-069, 7 May 1965.

4. AC-6 Ground Wind Launch Availability During Month of July, SD-65-140-CEN, 28 May 1965.

5. Surveyor/Centaur Reprogramming, GD/A-BNZ64-047, 11 January 1965 (Confidential).

6. Ground-Wind Restriction Procedure for Atlas/Centaur/Surveyor, AC-6 and AC-7, GD/C-BTD65-061, 1 June 1965.

7. Centaur Unified Test Plan, Hydraulic, Pneumatic, Air Conditioning and Heating (Ground) Test Parameters, Section 9.3.2B, AY62-0047, 10 May 1965.

8. Atlas/Centaur Launch-On-Time Study Bimonthly Report, GD/A-BNZ64-025-3, 10 November 1964.

9. Atlas/Centaur Launch-On-Time Study Bimonthly Report, (Surveyor Mission) GD/A-BNZ64-025-4, 6 January 1965.

10. Atlas/Centaur Launch-On-Time Study Monthly Progress Report, GD/A-ACY 65-001-1A, 12 February 1965.

11. Atlas/Centaur Launch-On-Time Study Bimonthly Report (Surveyor Mission) GD/C-ACY65-001-3, 7 May 1965.

APPENDIX A

COMPLEX 36A GSE AND FACILITY SYSTEMS

RESERVE DATA CALCULATIONS AND GENERAL

SYSTEM SCHEMATICS

ETR COMPLEX 36A

LAUNCH PERFORMANCE RESERVE ANALYSIS

LO_2 TRANSFER SYSTEM

Storage capacity	54,400 gal	
Fill tolerance	3,200	
Usable capacity		51,200 gal

Range Countdown Requirements

Atlas Tanking:

Vehicle volume	18,960 gal	
Boiloff: 60 minutes @ 40 gpm	2,400	
Engine bleeds: 60 minutes @ 10 gpm	600	
Total Atlas LO_2		21,960 gal

Centaur Tanking:

Vehicle volume	2,775 gal	
Boiloff: 70 minutes @ 3 gpm	210	
Total Centaur LO_2		2,985 gal
GSE Chilldown losses (estimated)		4,000 gal
Total Range Countdown LO_2		28,945 gal

Abort Requirement

None

Usage Rate

53 gpm (Atlas & Centaur Boiloff)

Reserve Time Available

LO_2 available for holding, 51,200 - 28,945 = 22,255 gal

$$\text{Reserve time} = \frac{22,255}{53} \simeq \underline{\underline{420 \text{ minutes}}}$$

LO_2 STORAGE TANK HELIUM SUPPLY

Storage capacity (water volume), 4 trailers, 1392 ft^3

Maximum pressure 2150 psig, $\rho = 1.4\ lb/ft^3$

Minimum pressure 600 psig, $\rho = 0.4\ lb/ft^3$

(assume temperature 70° F, 530° R)

Usable capacity = (1.4 - 0.4) (1392) = 1392 lb

Range Countdown Requirements

Helium required to transfer all LO_2 in storage tanks

Tank No. 1

Volume 4,120 ft^3

Initial Pressure 15 psia, $\rho = 0.029\ lb/ft^3$

Final pressure 65 psia, $\rho = 0.121\ lb/ft^3$

(assume temperature -260° F, 200° R)

Helium required (0.121 - 0.029) (4120) = 379 lb

Tank No. 2

Volume 3,820 ft^3

Initial pressure 15 psia, $\rho = 0.029\ lb/ft^3$

Final pressure 115 psia, $\rho = 0.215\ lb/ft^3$

(assume temperature -260° F, 200° R)

Helium required (0.215 - 0.029) (3820) = 710 lb

Total Helium required for LO_2 transfer 1089 lb

Abort Requirement

None

Usage Rate

0

Reserve Time Available

∞

LH_2 TRANSFER SYSTEM

Storage capacity	28,000 gal	
Fill tolerance	3,000	
Usable capacity		25,000 gal

Range Countdown Requirements

Vehicle tank volume	9,400 gal	
Boiloff: 40 minutes @ 45 gpm	1,800	
GSE Childown losses (estimated)	1,500	
GSE Pressurization losses *	1,100	
Total range countdown LH_2		13,800 gal

Abort Requirement

None

Usage Rate

45 gpm (maximum boiloff rate)

Reserve Time Available

LH_2 available for holding, 25,000 - 13,800 = 11,200 gal

$$\text{Reserve time} = \frac{11,200}{45} = \underline{\underline{249 \text{ minutes}}}$$

* GSE Pressurization losses:

Total storage volume 4120 ft^3

Transfer pressure 52 psia, $p = 0.216 \text{ lb/ft}^3$

Initial pressure 15 psia, $p = 0.056 \text{ lb/ft}^3$

(assume ullage temperature 52° R)

$$LH_2 \text{ required} = \frac{0.160 \ (4120)}{0.602 \text{ lb/gal}} = 1,100 \text{ gal}$$

LHe SYSTEM

Storage capacity	1,000 gal	
Fill tolerance	100	
Usable capacity		900 gal

Range Countdown Requirements

Storage tank pressurization losses (1)	35 gal	
GSE chilldown losses (2)	40	
LHe flow to vehicle: 17 minutes @ 5 gpm	85	
Total range countdown LHe		160 gal

Abort Requirement

None

Usage Rate

3 - 5 gpm

Reserve Time Available

LHe available for holding, 900 - 160 = 740 gal

$$\text{Reserve time} = \frac{740}{5} = \underline{\underline{148 \text{ minutes}}}$$

(1) Storage tank pressurization:

Total storage volume

Transfer pressure 52 psia, $p = 0.365 \text{ lb/ft}^3$

Initial pressure 15 psia, $p = 0.11 \text{ lb/ft}^3$

(assume ullage temperature = 53°R)

$$\text{LHe required} = \frac{0.255\ (147)}{1.07 \text{ lb/gal}} = 35 \text{ gal}$$

(2) Includes time from flow control valve open to P & W engine turbopump temperature of -310° F

LN_2 SYSTEM, FACILITY

Storage capacity	20,000 gal	
Fill tolerance	1,000	
Usable capacity		19,000 gal

Range Countdown Requirements

Atlas Helium bottle shrouds:		
Rapid fill: 7 minutes @ 75 gpm	525 gal	
Topping: 83 minutes @ 10 gpm	830	
LO_2 Subcooler:		
Fill	822	
Chilldown	80	
Topping: 34 minutes @ 6 gpm	204	
Facility Recharger:		
340 minutes @ 3.4 gpm (≃22 lb/minute) ①	1,160	
Total Range Countdown LN_2		3,621 gal

Abort Requirement

Facility recharger:		
60 minutes @ 3.4 gpm	200 gal	
Total Abort LN_2		200 gal

Usage Rate

Approximately 26.7 gpm

Reserve Time Available

LN_2 available for holding, 19,000 - 3,821 = 15,179 gal

Reserve time $\frac{15,179}{26.7} \simeq \underline{\underline{570 \text{ minutes}}}$

① Facility recharger has a recharge capability of approximately 60 lb/minute. The rate used in these calculations is the demand rate to maintain the routine GN_2 system at an acceptable pressure level.

LN_2 SYSTEM, AIR CONDITIONING

Storage capacity	28,000 gal	
Fill tolerance	2,000	
Usable capacity		26,000 gal (177,000 lb)

Range Countdown Requirements

Surveyor air conditioning:		
96 minutes @ 78.5 lb/minute	7,530 lb	
Forward compartment cooling:		
96 minutes @ 75 lb/minute	7,200 lb	
Interstage adapter heating:		
96 minutes @ 160 lb/minute	15,360 lb	
Atlas pod cooling:		
96 minutes @ 37 lb/minute	3,550 lb	
Leakage allowance:		
96 minutes @ 18 lb/minute	1,730 lb	
Total range countdown LN_2		35,370 lb

Abort Requirements

Surveyor air conditioning:		
60 minutes @ 78.5 lb/minute	4,710 lb	
Forward compartment cooling (1):		
120 minutes @ 75 lb/minute	9,000 lb	
Interstage adapter heating (2):		
240 minutes @ 160 lb/minute	38,400 lb	
Atlas pod cooling (1):		
120 minutes @ 37 lb/minute	4,440 lb	
Leakage allowance (2):		
240 minutes @ 18 lb/minute	4,320 lb	
Total abort GN_2		60,870 lb

LN_2 SYSTEM, AIR CONDITIONING (Continued)

Usage Rate

368.5 lb/minute

Reserve Time Available

LN_2 available for holding, 177,000 - 96,240 = 80,760 lb

$$\text{Reserve time} = \frac{80,760}{368.5} \simeq \underline{\underline{219 \text{ minutes}}}$$

1 Time assumes manual securing at T+120 minutes.

2 Figures assume abort after T-3 seconds.

HELIUM SYSTEM, PRESSURIZATION SUPPLY

Primary Supply, 3,000 psig

Storage capacity (water volume) 403.1 ft^3

Maximum pressure 3,000 psig, $p = 1.91 \ lb/ft^3$

Minimum pressure 1,200 psig, $p = 0.81 \ lb/ft^3$

(Assume temperature 70° F, 530° R)

Usable capacity (1.91 - 0.81) 403.1 = 443 lb = 42,800 scf

Range Countdown Requirements

Atlas Propellant tank pressurization	1,800 scf	
LHe transfer line/P & W engine purge (1)	5,650	
Error contingencies (10% x gross)	4,580	
Total range countdown helium		12,030 scf

Abort Requirements

LHe transfer line/P & W engine purge	12,000 scf	
Total abort helium		12,000 scf

Usage Rate

50 scfm (LHe transfer line/P & W engine purge)

Reserve Time Available

Helium available for holding, 42,800 - 24,030 = 18,770 scf

$$\text{Reserve time} = \frac{18,770}{50} = \underline{\underline{375 \text{ minutes}}}$$

(1) Estimated flow rate

HELIUM SYSTEM, PRESSURIZATION SUPPLY (Continued)

Emergency Supply, 6,000 psig

Storage capacity (water volume) $331.1\ ft^3$

Maximum pressure 6,000 psig, $p = 3.4\ lb/ft^3$

Minimum pressure 3,550 psig, $p = 2.2\ lb/ft^3$

(assume temperature 70°F, 530°R)

Usable capacity = (3.4 - 2.2) 331.1 = 397 lb = 38,400 scf

Range Countdown Requirements

Atlas airborne helium bottle charge	16,740 scf	
Centaur propellant tank pressurization	350	
Centaur airborne helium bottle charge (1)	470	
Centaur inflight purge bottle charge	470	
P & W engine blowdowns	350	
Error contingencies (10% gross)	3,840	
Total range countdown helium		22,220 scf

Abort Requirements

LH_2 tank purge	8,400 scf	
Total abort helium		8,400 scf

Usage Rate

0

Reserve Time Available

∞

(1) For 2-burn missions, the helium required for bottle pressurization is 830 scf which increases the helium required for range countdown to approximately 22,780 scf.

HELIUM SYSTEM, INSULATION PANEL PURGE SUPPLY

Storage capacity (water volume)	$2,205\ ft^3$	
Maximum pressure	6,000 psig, $p = 3.4\ lb/ft^3$	
Minimum pressure	1,000 psig, $p = 0.68\ lb/ft^3$	
(assume temperature 70° F, 530° R)		
Usable capacity = (3.4 - 0.68) 2,205 =		6,000 lb

Range Countdown Requirements

Centaur Vehicle purges:

- Insulation panel purge
- P & W engine injector purge
- Hydraulic pump coupling purge
- LH_2 low pressure duct purge
- P & W seal cavity purge
- LO_2 & LH_2 boost pump seal purge

Total purges - high flow rate 280 lb/hour		
Helium required, 130 minutes @ 280 lb/hour	605 lb	
Total purges - low flow rate 120 lb/hour		
Helium required, 210 minutes @ 120 lb/hour	420 lb	
Error contingencies (10% x gross)	600 lb	
Total range countdown helium		1,625 lb

Abort Requirements

Total purges - high flow rate		
Helium required, 60 minutes @ 280 lb/hour	280 lb	
Total purges - low flow rate		
Helium required, 210 minutes @ 120 lb/hour	360 lb	
Total abort helium		640 lb

Usage Rate

280 lb/hour (high flow rate)

Reserve Time Available

Helium available for holding, 6,000 - 2,265 = 3,735 lb

$$\text{Reserve time} = \frac{3,735}{280}(60) = \underline{\underline{800 \text{ minutes}}}$$

GN_2 SYSTEM, ROUTINE USE

Storage capacity (water volume) 1,100 ft^3

Maximum pressure 2,400 psig, p = 11.5 lb/ft^3

Minimum pressure 1,100 psig, p = 5.4 lb/ft^3

(assume temperature 70° F, 530° R)

Usable capacity = (11.5 - 5.4) 1,100 = 6,710 lb

Range Countdown Requirements

LH_2 vent stack purge (vehicle):		
6 minutes @ 10 lb/minute	60 lb	
LH_2 vent stack purge (storage tank):		
60 minutes @ 10 scfm	45 lb	
Atlas gas generator purges:		
10 minutes @ 130 scfm	90 lb	
Atlas LO_2 dome purges:		
10 minutes @ 730 scfm	520 lb	
Atlas hypergol purge:		
10 minutes @ 50 scfm	35 lb	
Terminal box purges, controls & system bleeds:		
340 minutes @ 100 scfm (estimated)	2,400 lb	
LN_2 storage tank pressurization (air conditioning) (2):		
Initial pressurization	1,300 lb	
LN_2 flow support 90 minutes @ 13.9 lb/min	1,250 lb	
Umbilical boom hydraulic system charge	55 lb	
Total range countdown GN_2		5,755 lb

Abort Requirements

LH_2 vent stack purge (vehicle):	
3 minutes @ 10 lb/minute	30 lb
Atlas LO_2 dome purge:	
10 minutes @ 730 scfm	520 lb
Terminal box purges, controls & system bleeds:	
240 minutes @ 100 scfm (estimated)	1,700 lb

GN_2 SYSTEM, ROUTINE USE (Continued)

Abort Requirements (Continued)

LN_2 storage tank pressurization (air conditioning) (1):

60 minutes @ 13.9 lb/minute	835 lb	
180 minutes @ 5.5 lb/minute	990 lb	
Total abort GN_2		4,075 lb

Usage Rate

Case A - 21.7 lb/minute

Case B - 7.8 lb/minute

Reserve Time Available

The estimated GN_2 usage for routine use in addition to the required GN_2 to pressurize the air conditioning system LN_2 storage tank exceeds the system capacity by 3,120 pounds making it essential to utilize the facility recharger. In the event the facility recharger is inoperable, the air conditioning backup system will be utilized, relieving the demand on the routine GN_2 storage supply.

A. Reserve Time for Routine GN_2 System with Facility Recharger

The facility recharger has a maximum capacity of 60 pounds per minute which far exceeds the demand flow of routine GN_2 system including the air conditioning LN_2 storage tank demand flow. Therefore:

$$\text{Reserve Time} = \text{facility } LN_2 \text{ system reserve time} + \frac{GN_2 \text{ usable capacity}}{GN_2 \text{ usage rate}}$$

$$= 570 + \frac{6,710}{21.7} = 570 + 309 \simeq \underline{\underline{879 \text{ minutes}}}$$

B. Reserve Time for Routine GN_2 System without Facility Recharger

In this case, the LN_2 air conditioning demand flow is deleted providing the following:

Range countdown usage - 3,205 lb

Abort usage - 2,250 lb

Usage rate - 7.8 lb/minute

$$\text{Reserve time} = \frac{6710 - 5455}{7.8} = \underline{\underline{161 \text{ minutes}}}$$

(1) Exclude for case B reserve time calculations.

GN_2 SYSTEM, AIR CONDITIONING SUPPLY BACKUP

Storage capacity (water volume)		17,040 ft^3	
Maximum pressure	2,400 psig, ρ = 11.5 lb/ft^3		
Minimum pressure	600 psig, ρ = 2.9 lb/ft^3		
(assume temperature 70° F, 530° R)			
Usable capacity = (11.5 - 2.9) 17,040 =			146,500 lb

Range Countdown Requirements

Surveyor air conditioning:		
96 minutes @ 78.5 lb/minute	7,530 lb	
Forward compartment cooling:		
96 minutes @ 75 lb/minute	7,200 lb	
Interstage adapter heating:		
96 minutes @ 160 lb/minute	15,360 lb	
Atlas pod cooling:		
96 minutes @ 37 lb/minute	3,550 lb	
Leakage allowance:		
96 minutes @ 18 lb/minute	1,730 lb	
Total range countdown GN_2		35,370 lb

Abort Requirements

Surveyor air conditioning:		
60 minutes @ 78.5 lb/minute	4,710 lb	
Forward compartment cooling (1):		
120 minutes @ 75 lb/minute	9,000 lb	
Interstage adapter heating (2):		
240 minutes @ 160 lb/minute	38,400 lb	
Atlas pod cooling (1):		
120 minutes @ 37 lb/minute	4,440 lb	
Leakage allowance:		
240 minutes @ 18 lb/minute	4,320 lb	
Total abort GN_2		60,870 lb

Usage Rate

368.5 lb/minute

Reserve Time Available

GN_2 available for holding, 146,500 - 96,240 = 50,260 lb

$$\text{Reserve time} = \frac{50,260}{368.5} = \underline{\underline{136 \text{ minutes}}}$$

(1) Time shown assumes manual securing of GN_2 flow at T+120 minutes.

(2) Figure assumes abort after T-3 seconds.

GN_2 SYSTEM, HOLD-DOWN & RELEASE

Storage capacity (water volume)	$80\ ft^3$	
Maximum pressure	8,000 psig, $p = 27\ lb/ft^3$	
Minimum pressure	6,000 psig, $p = 23.5\ lb/ft^3$	
(assume temperature 70° F, 530° R)		
Usable capacity = (27 - 23.5) 80 =		280 lb

Range Countdown Requirements

Pressurize launcher hold-down and release Cylinders to 5,750 psig	12 lb	
Nose fairing jettison bottle 1,740 in.^{3} @ 2,535 psig	15 lb	
Launcher stabilization system	14 lb	
Error contingencies (10% x gross)	28 lb	
Total range countdown GN_2		69 lb

Abort Requirements

None

Usage Rate

0

Reserve Time Available

∞

GN_2 SYSTEM, ATLAS THRUST SECTION HEATING

Storage capacity (water volume) 1 trailer 274 ft^3

Maximum pressure 2,250 psig, p = 11 lb/ft^3

Minimum pressure 1,100 psig, p = 5.4 lb/ft^3

(assume temperature 70° F, 530° R)

Usable capacity = (11 - 5.4) 274 = 1,530 lb

Range Countdown Requirements

Atlas thrust section heating

5 minutes @ 80 lb/minute 400 lb

Total range countdown GN_2 400 lb

Abort Requirements

None

Usage Rate

80 lb/minute

Reserve Time Available

GN_2 available for holding, 1,530 - 400 = 1,130 lb

$$\text{Reserve time} = \frac{1,130}{400} = 14 \text{ minutes}$$

NOTE: During the range countdown this system is used to provide an inert atmosphere in the Atlas thrust section prior to engine start. This system can be secured and flow restarted in the event of a hold after T-5 minutes. The 14-minute reserve time provides a minimum of three additional flows due to countdown delays.

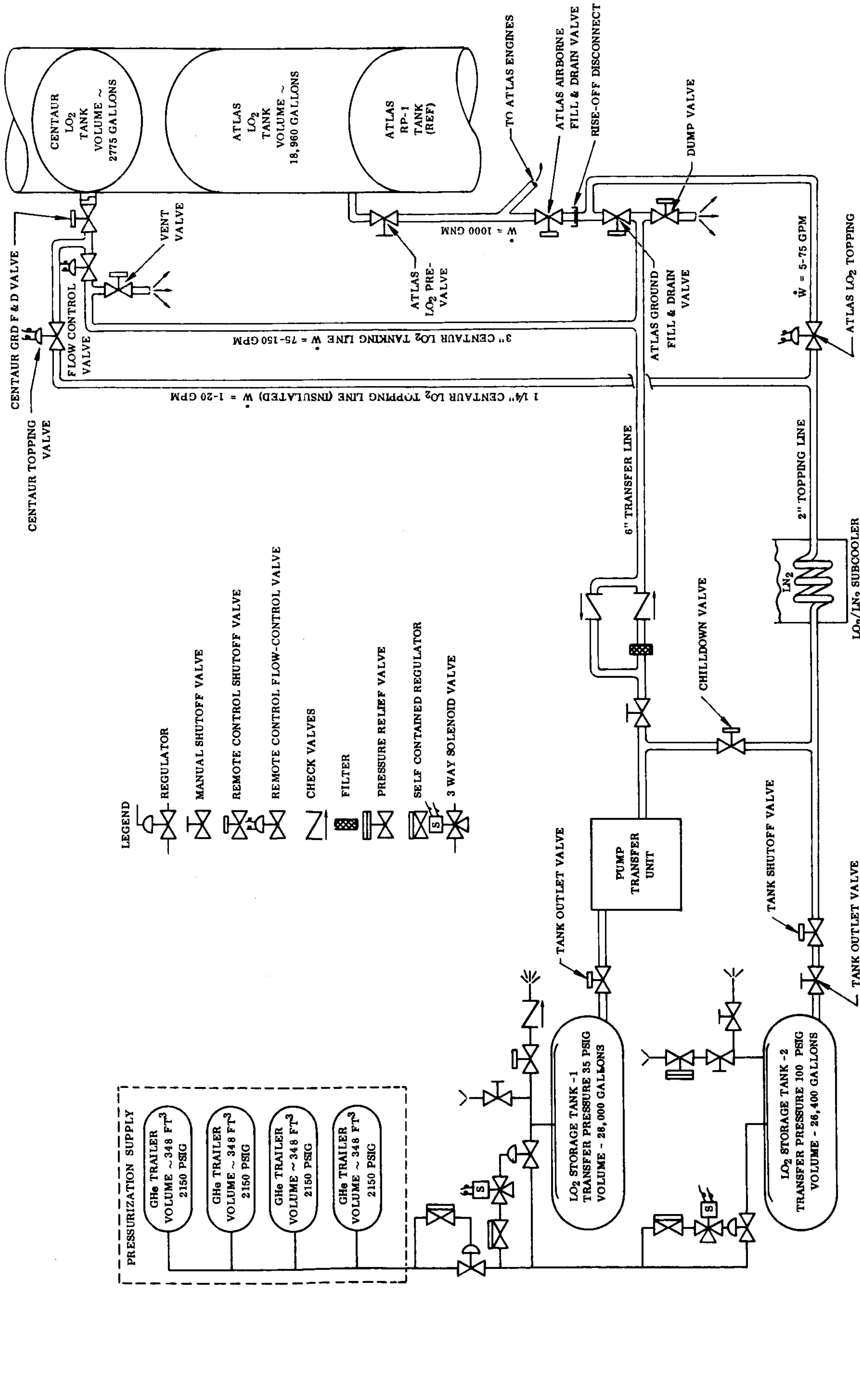


Figure A-1. Complex 36A - LO_2 Transfer System (Simplified Schematic)

4K21LT

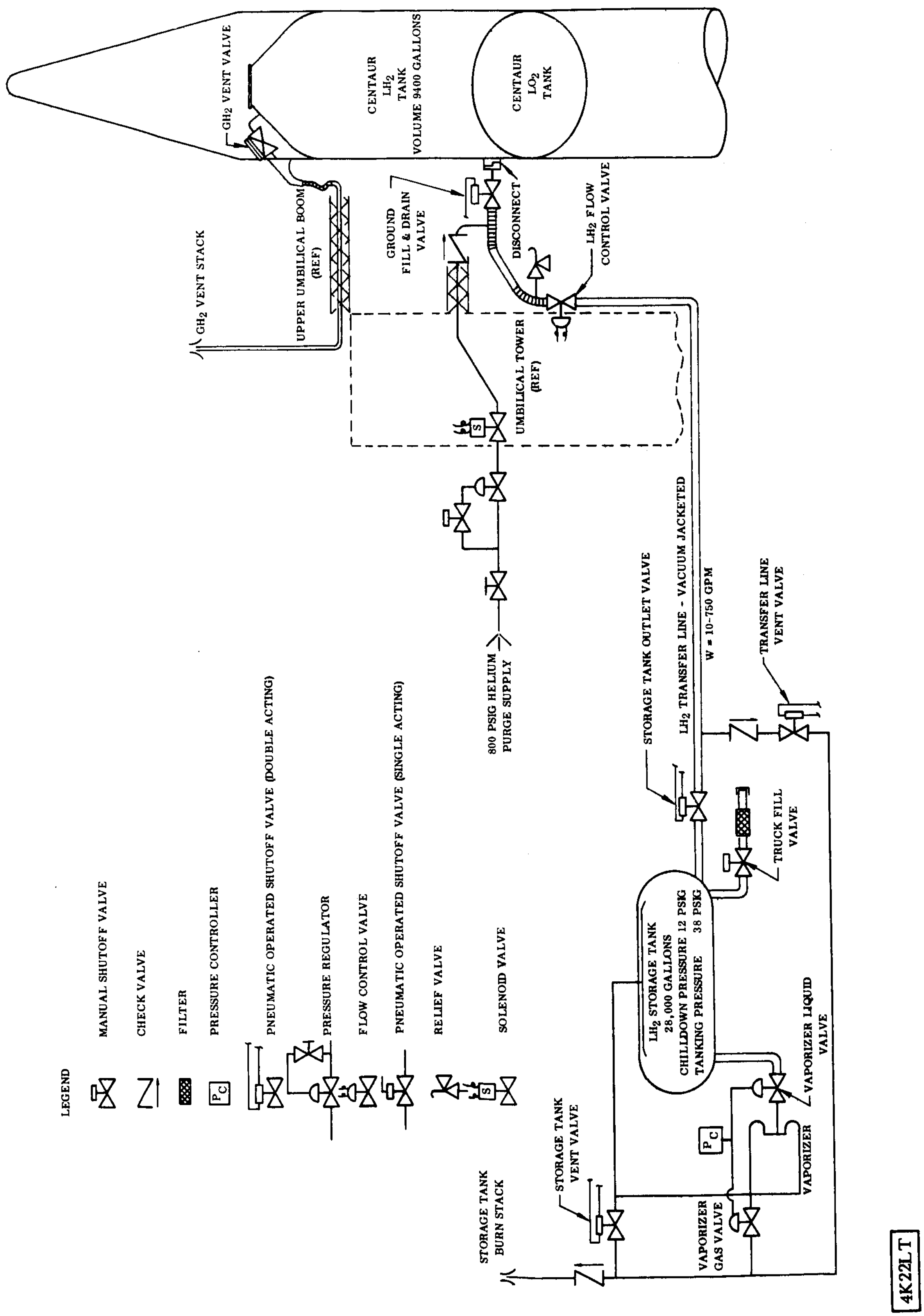


Figure A-2. Complex 36A - LH_2 Transfer Systems (Simplified Schematic)

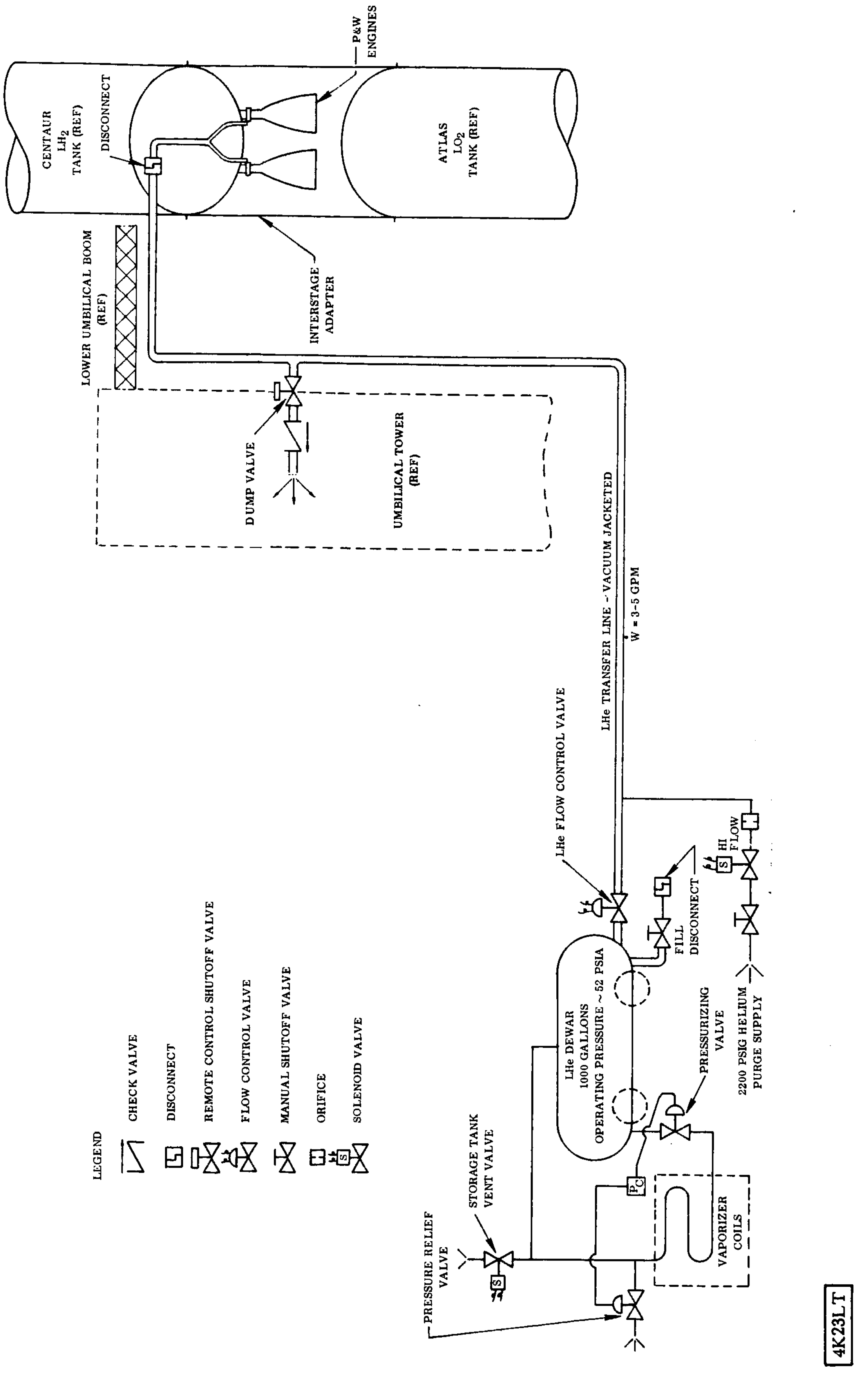
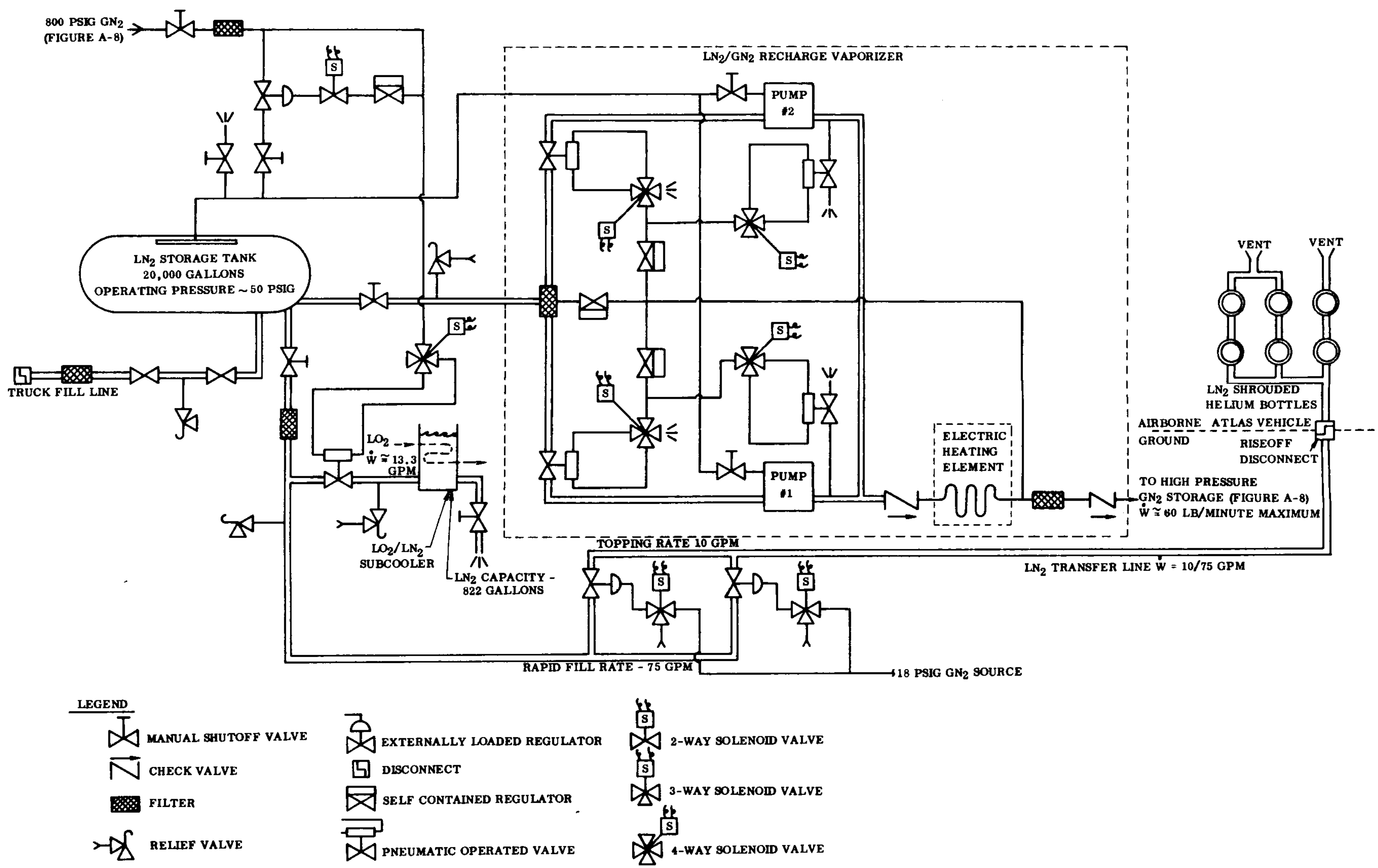


Figure A-3. Complex 36A - LHe Transfer System (Simplified Schematic)



4K24LT

Figure A-4. Complex 36A - Facility LN_2 System (Simplified Schematic)

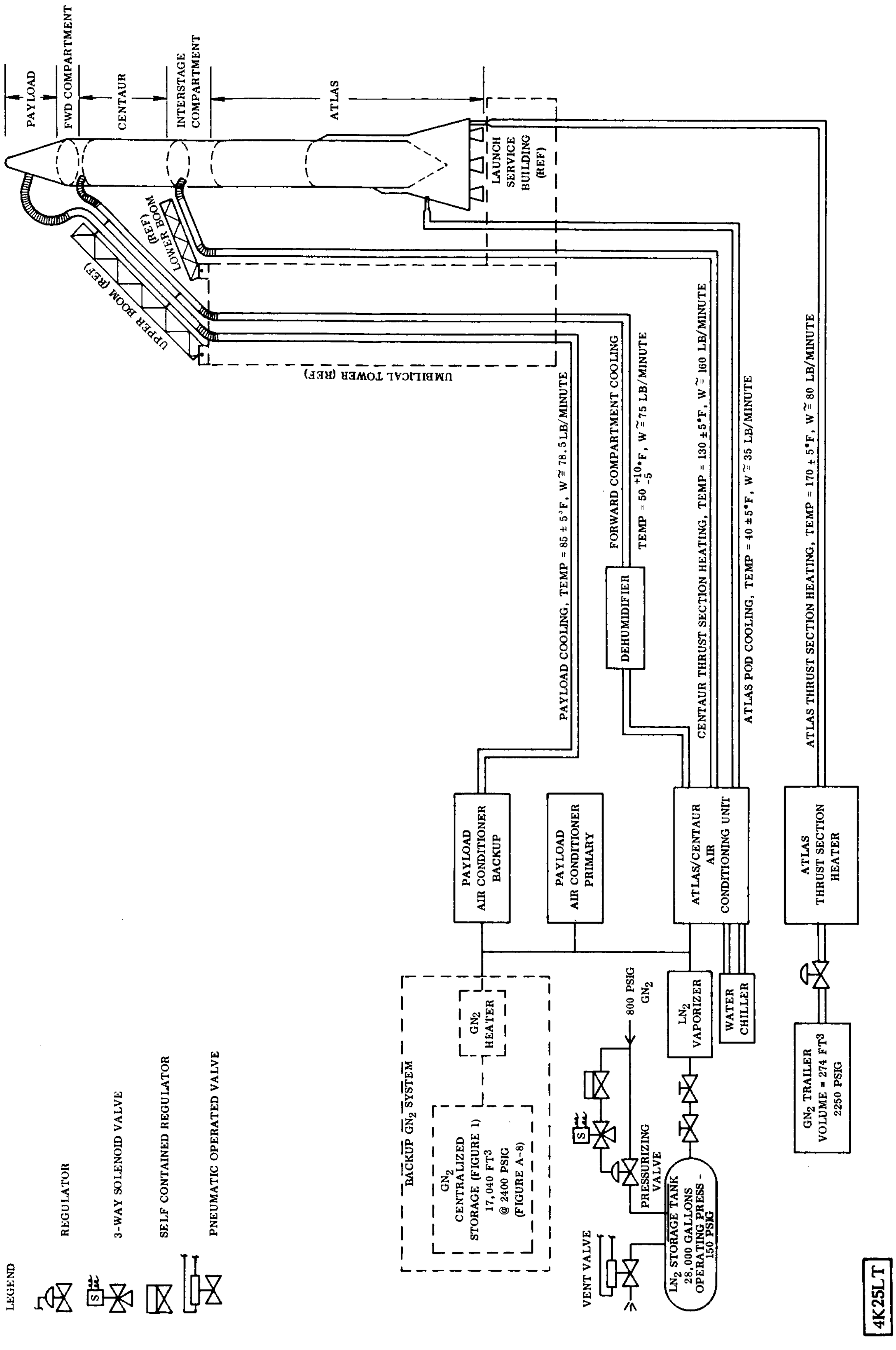


Figure A-5. Complex 36A - Vehicle Air Conditioning GN_2 System

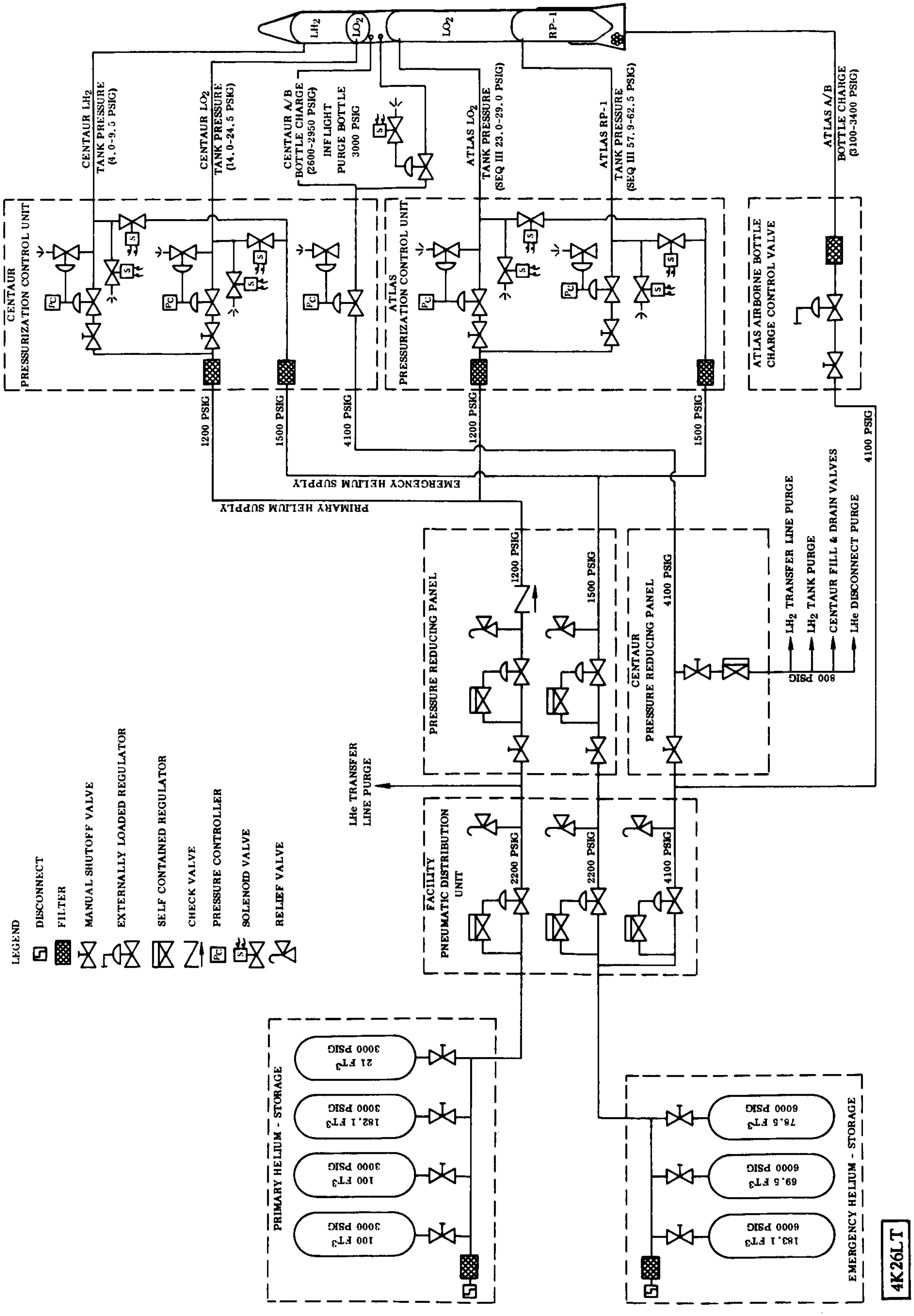


Figure A-6. Complex 36A - Helium Pressurization System (Simplified Schematic)

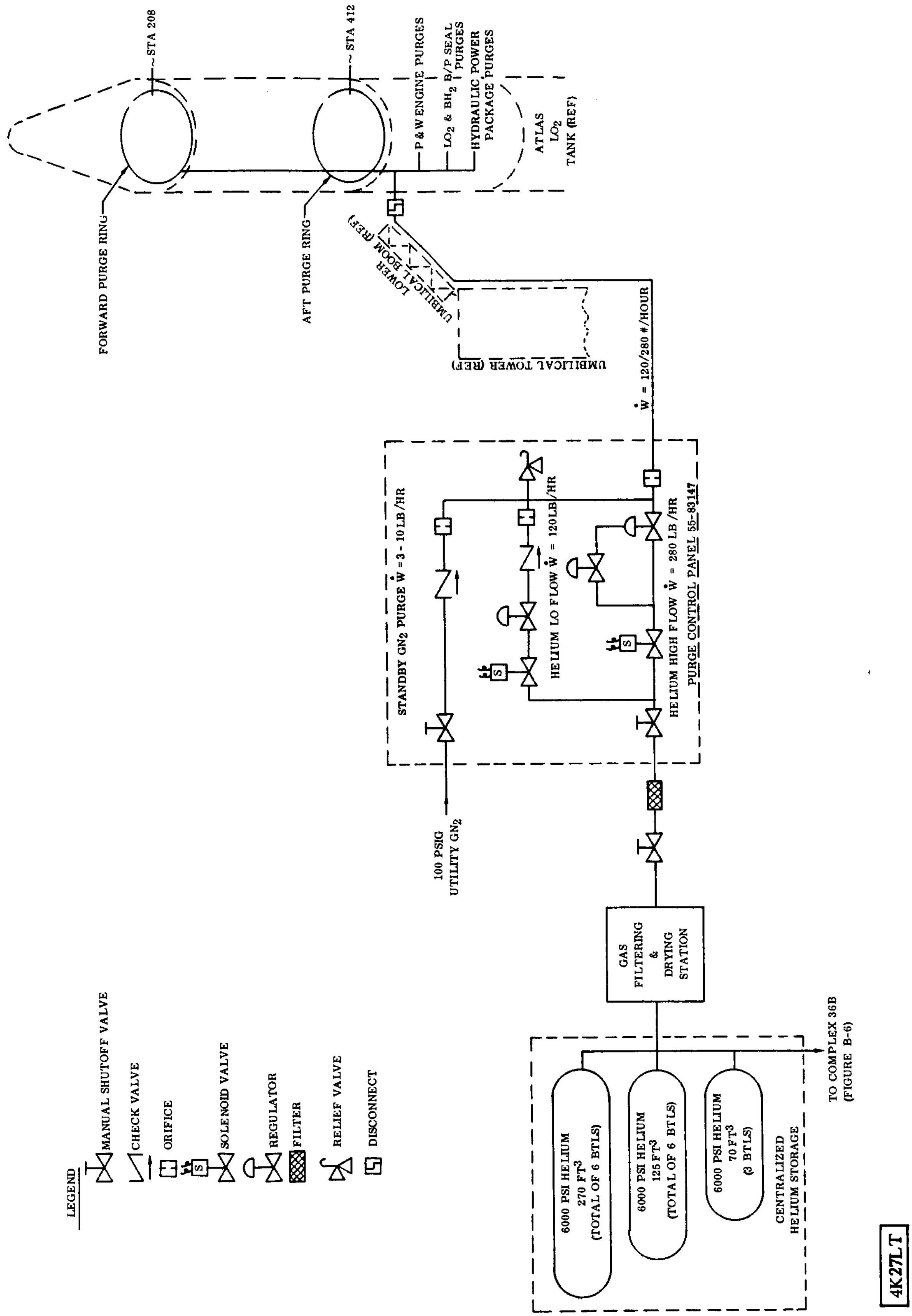


Figure A-7. Complex 36A - Insulation Panel Purge Helium System (Simplified Schematic)

4K27LT

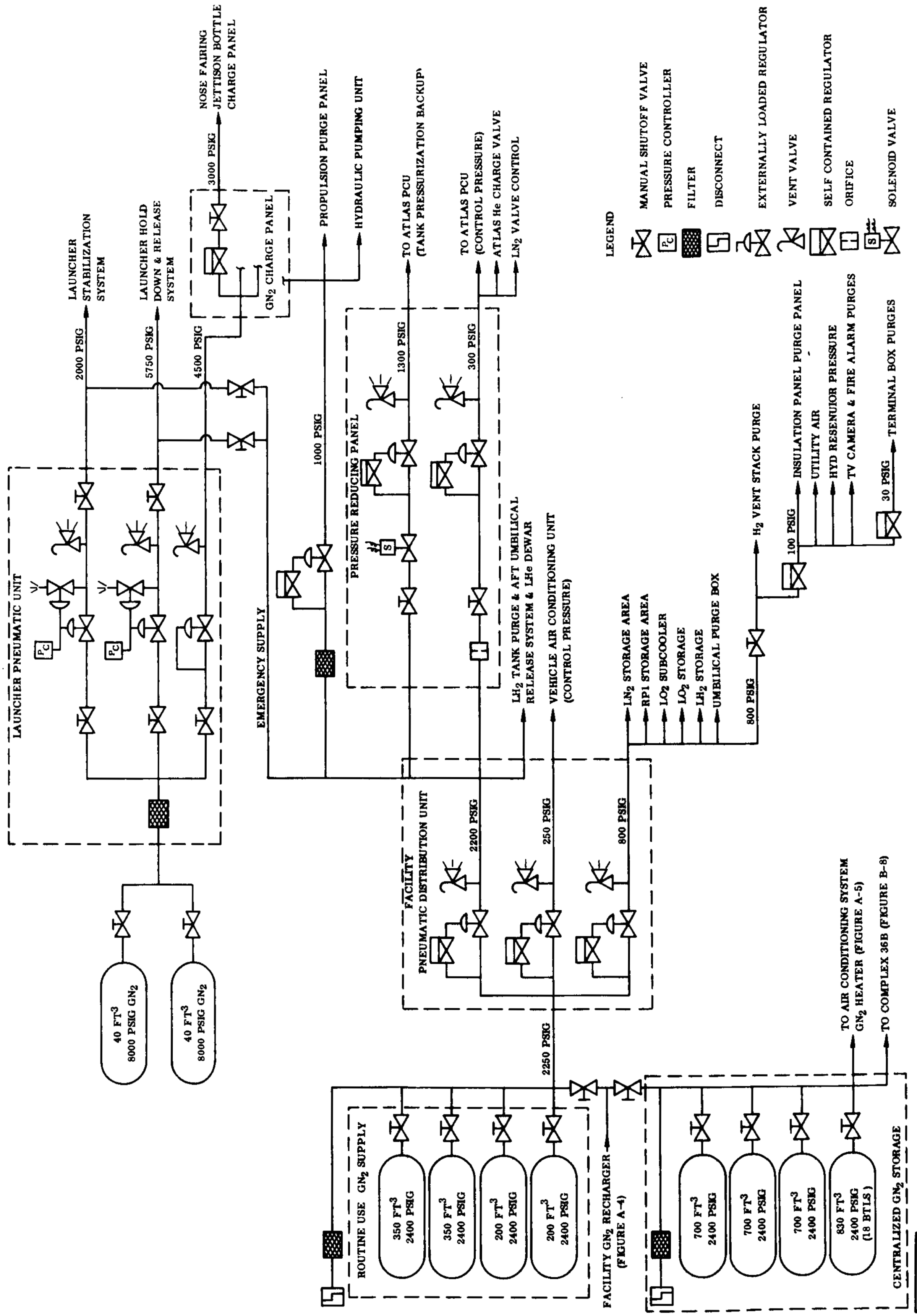
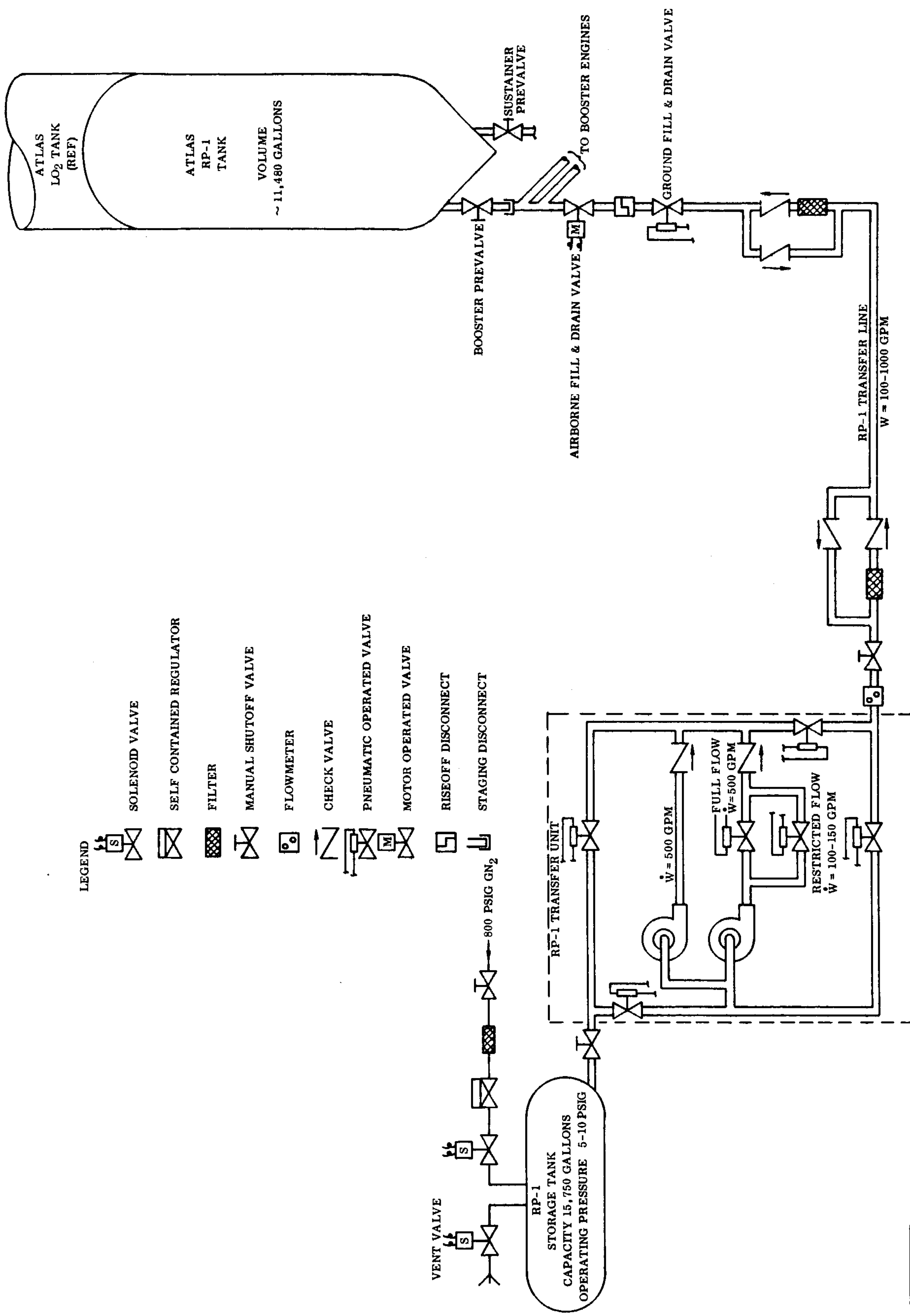
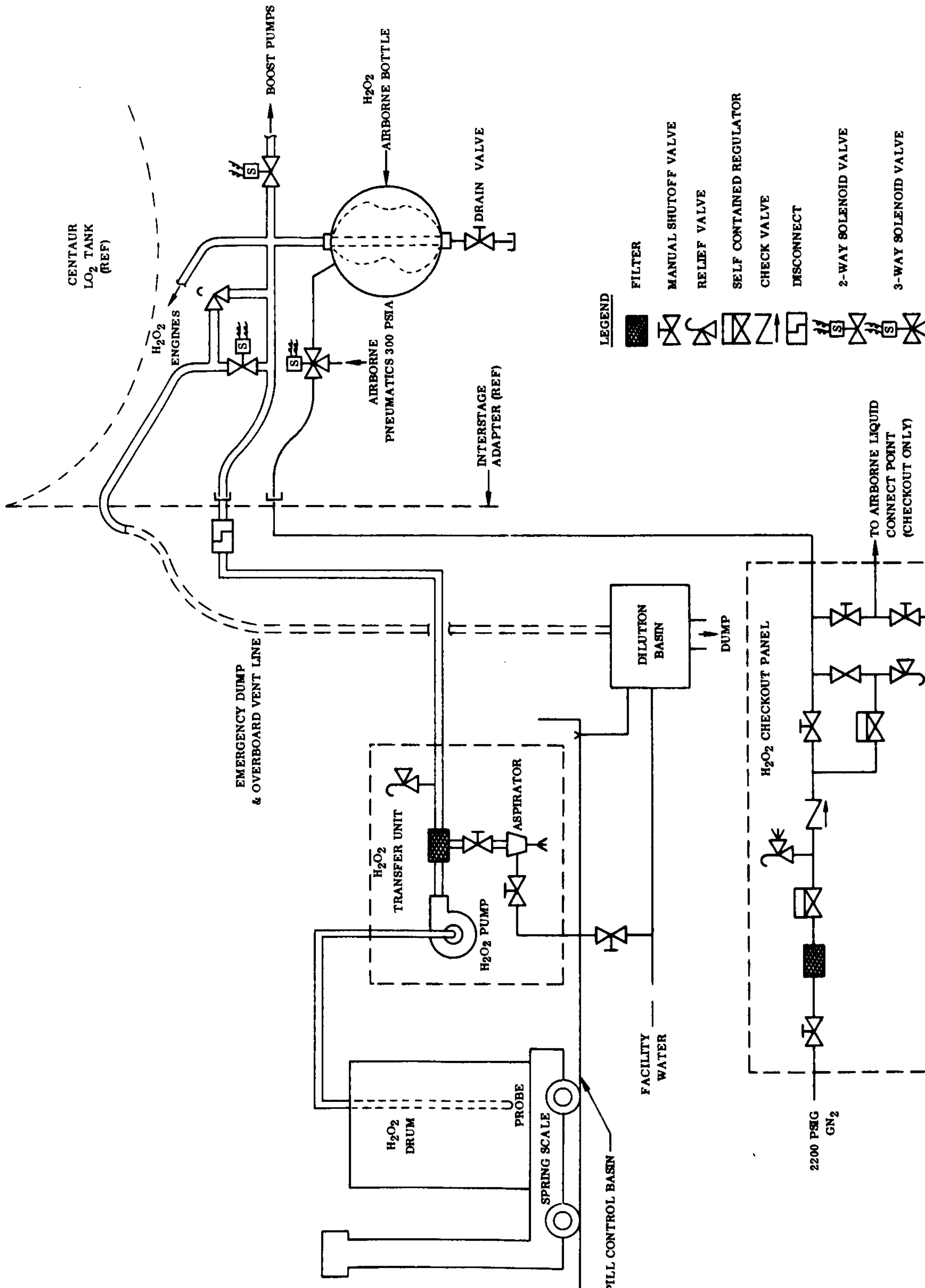


Figure A-8. Complex 36A - Routine Use GN$_2$ System (Simplified Schematic)



4K29LT

Figure A-9. Complex 36A - Atlas Fuel Transfer System (Simplified Schematic)



4K30LT

Figure A-10. Complex 36A - Hydrogen Peroxide Transfer System (Simplified Schematic)

APPENDIX B

COMPLEX 36B GSE AND FACILITY SYSTEMS

RESERVE DATA CALCAULATIONS AND GENERAL

SYSTEM SCHEMATICS

ETR COMPLEX 36B

LAUNCH PERFORMANCE RESERVE ANALYSIS

LO_2 TRANSFER SYSTEM

Storage capacity	38,000 gal	
Fill tolerance	1,500	
Usable capacity		36,500 gal

Range Countdown Requirements

Atlas tanking:		
Vehicle volume	18,960 gal	
Boiloff 60 minutes @ 40 gpm	2,400	
Engine bleeds 60 minutes @ 10 gpm	600	
Total Atlas LO_2		21,960 gal
Centaur tanking:		
Vehicle volume	2,775 gal	
Boiloff 70 minutes @ 3 gpm	210	
Total Centaur LO_2		2,985 gal

GSE Pressurization losses

Total storage volume 5,653 ft^3

Maximum pressure 165 psia, $p = 2.8\ lb/ft^3$

Initial pressure 15 psia, $p = 0.29\ lb/ft^3$

(assume ullage temperature 216° R)

LO_2 required $(2.8 - 0.29)(5,653)\left(\frac{7.48}{69.3}\right) =$ 1,530 gal

GSE chilldown losses (estimated) 3,000 gal

Total range countdown LO_2 29,475 gal

Abort Requirement

None

LO_2 TRANSFER SYSTEM (Continued)

Usage Rate

53 gpm (Atlas & Centaur boiloff)

Reserve Time Available

LO_2 available for holding, 36,500 - 29,475 = 7,025 gal

$$\text{Reserve time} = \frac{7,025}{53} \simeq \underline{\underline{133 \text{ minutes}}}$$

LH_2 TRANSFER SYSTEM

Storage capacity	28,000 gal	
Fill tolerance	3,000	
Usable capacity		25,000 gal

Range Countdown Requirements

Vehicle tank volume	9,400 gal	
Boiloff 40 minutes @ 45 gpm	1,800	
GSE chilldown losses (estimated)	1,500	
GSE pressurization losses*	1,100	
Total range countdown LH_2		13,800 gal

Abort Requirement

None

Usage Rate

45 gpm (maximum boiloff rate)

Reserve Time Available

LH_2 available for holding, 25,000 - 13,000 = 11,200 gal

$$\text{Reserve time} = \frac{11,200}{45} = \underline{\underline{249 \text{ minutes}}}$$

*GSE pressurization losses

Total storage volume	4,120 ft^3
Transfer pressure	52 psia, $p = 0.216\ lb/ft^3$
Initial pressure	15 psia, $p = 0.056\ lb/ft^3$

(assume ullage temperature 52° R)

$$LH_2 \text{ required} = \frac{0.160\ (4,120)}{0.602\ lb/gal} = 1,100 \text{ gal}$$

LHe SYSTEM

Storage capacity	1,000 gal	
Fill tolerance	100	
Usable capacity		900 gal

Range Countdown Requirements

Storage tank pressurization ①	35 gal	
GSE chilldown losses ②	40 gal	
LHe flow to vehicle 17 minutes @ 5 gpm	85	
Total range countdown LHe		160 gal

Abort Requirement

None

Usage Rate

3 - 5 gpm

Reserve Time Available

LHe available for holding, 900 - 160 = 740 gal

Reserve time $= \frac{740}{5} = \underline{\underline{148 \text{ minutes}}}$

① Storage tank pressurization:

Total storage volume 147 ft^3

Transfer pressure 52 psia, $p = 0.365$ lb/ft^3

Initial pressure 15 psia, $p = 0.11$ lb/ft^3

(assume ullage temperature = 53° R)

LHe required $= \frac{0.255\ (147)}{1.07\ \text{lb/gal}} = 35$ gallons

② Includes time from flow control valve open to P & W engine turbopump temperature of -310° F.

LH_2 SYSTEM

Storage capacity	28,000 gal	
Fill tolerance	3,000	
Usable capacity		25,000 gal

Range Countdown Requirements

Atlas helium bottle shrouds:

Rapid fill 7 minutes @ 35 gpm = 245 gal
Topping 83 minutes @ 10 gpm = 830

LO_2 transfer system subcooler = 1,800

Total range countdown LN_2	2,875 gal

Abort Requirement

None

Usage Rate

10 gpm (Atlas helium bottle shroud boiloff)

Reserve Time Available

LN_2 available for holding, 25,000 - 2,875 = 22,125 gal

$$\text{Reserve time} = \frac{22,125}{10} = 2,212 \text{ minutes}$$

LO_2/LN_2 SUBCOOLER

Total capacity, LN_2	1,775 gal	
Minimum level	571	
Usable LN_2		1,204 gal

Range Countdown Requirements

LN_2 boiloff rate 1/4 gal/gal LO_2*

Centaur topping	38 gal	
Atlas topping	190	
Total range countdown LN_2		228 gal

Abort Requirement

None

Usage Rate

1/4 gal LN_2/gal LO_2, = 13.3 gpm*

Reserve Time Available

LN_2 available for holding, 1,204 - 228 = 976 gal

$$\text{Reserve time} = \frac{976}{1/4\ (\text{total } LO_2 \text{ topping rate})}$$

$$= \frac{976\ (4)}{53} = 73.6 \text{ minutes}$$

*Estimated value

LN_2 STORAGE TANK PRESSURIZING SYSTEM, GN_2

Storage capacity (water volume) 700 ft^3
Maximum pressure 1500 psig, $p = 7.8$ lb/ft^3
Minimum pressure 100 psig, $p = 0.5$ lb/ft^3
(assume temperature 70° F, 530° R)
Usable capacity = (7.8 - 0.5) 700 = 5,110 lb

Range Countdown Requirement

GN_2 required to transfer all LN_2 from storage tank:

Total volume (storage tank) 4,120 ft^3
Initial pressure, 15 psia, $p = 0.24$ lb/ft^3
Transfer pressure, 65 psia, $p = 1.1$ lb/ft^3
(assume ullage gas at saturation temp = 160° R)

1 GN_2 required = (1.1 - 0.24) (4,120 ft^3) = 3,540 lb
Excess GN_2 available 1,570 lb

Abort Requirement

None

Usage Rate

0

Reserve Time Available

∞

1 The calculation assumes that all of the gas used for pressurizing the storage tank will remain as a gas and can be used for liquid transfer. Because of the storage tank configuration and operating pressures, this assumption may not be valid. As soon as the consumption rate can be measured, the results of this analysis will be updated.

HELIUM SYSTEM, PRESSURIZATION SUPPLY

Storage capacity (water volume)	800 ft^3	
Maximum pressure 6,000 psig, $p = 3.4$ lb/ft^3		
Minimum pressure 3,550 psig, $p = 2.2$ lb/ft^3		
(assume temperature 70° F, 530° R)		
Usable capacity = (3.4 - 2.2) 800 =	960 lb =	92,800 scf

Range Countdown Requirements

Atlas propellant tank pressurization	1,800 scf	
Atlas airborne helium bottle charge	16,740	
Centaur propellant tank pressurization	350	
Centaur airborne helium bottle charge (1)	470	
Centaur inflight purge bottle charge	470	
LHe transfer line/P & W engine purges	5,650	
P & W engine blowdowns	350	
Error contingencies (10% gross)	9,280	
Total range countdown helium		35,110 scf

Abort Requirements

LH_2 tank purge	8,400 scf	
LHe transfer line/P & W engine purge	12,000 scf	
Total abort helium		20,400 scf

Usage Rate

50 scfm (LHe transfer line/P & W engine purge)

Reserve Time Available

Helium available for holding, 92,800 - 55,510 = 37,290 scf (1)

$$\text{Reserve Time} = \frac{37,290}{50} \simeq \underline{\underline{746 \text{ minutes}}} \; (1)$$

(1) For 2-burn missions, the helium required for bottle charge is 830 scf which reduces the helium available for holding to 36,930 scf and the reserve time to approximately 739 minutes.

HELIUM SYSTEM, INSULATION PANEL PURGE SUPPLY

Storage capacity (water volume)	2, 205 ft^3		
Maximum pressure 6, 000 psig, $p = 3.4\ lb/ft^3$			
Minimum pressure 1, 000 psig, $p = 0.68\ lb/ft^3$			
(assume temperature 70° F, 530° R)			
Usage capacity = (3. 4 - 0. 68) 2, 205 =			6, 000 lb

Range Countdown Requirements

Centaur Vehicle purges:

Insulation panel purge		
P & W engine injector purge		
Hydraulic pump coupling purge		
LH_2 low pressure duct purge		
P & W seal cavity purge		
LO_2 & LH_2 boost pump seal purge		
Total purges - high flow rate 280 lb/hour		
Helium required 130 minutes @ 280 lb/hour	605 lb	
Total purges - low flow rate 120 lb/hour		
Helium required 210 minutes @ 120 lb/hour	420 lb	
Error contingencies (10% × gross)	600 lb	
Total range countdown helium		1, 625 lb

Abort Requirements

Total purges - high flow rate		
Helium required 60 minutes @ 280 lb/hour	280 lb	
Total purges - low flow rate		
Helium required 180 minutes @ 120 lb/hour	360 lb	
Total Abort helium		640 lb

Usage Rate

280 lb/hour (high flow rate)

Reserve Time Available

Helium available for holding (6, 000 - 2, 265) = 3, 735 lb

$$\text{Reserve Time} = \frac{3,735}{280}(60) = \underline{\underline{800\ \text{minutes}}}$$

GN_2 SYSTEM, ROUTINE USE

Storage capacity (water volume)	800 ft^3	
Maximum pressure 6,000 psig, $p = 23.5\ lb/ft^3$		
Minimum pressure 2,300 psig, $p = 11.5\ lb/ft^3$		
(assume temperature 70° F, 530° R)		
Usable capacity = (23.5 - 11.5) 800 =		9,600 lb

Range Countdown Requirements

LH_2 vent stack purge (vehicle)	60 lb	
6 minutes @ 10 lb/min		
LH_2 vent stack purge (storage tank)	45 lb	
60 minutes @ 10 scfm		
Atlas gas generator purges	90 lb	
10 minutes @ 130 scfm		
Atlas LO_2 dome purges	520 lb	
10 minutes @ 730 scfm		
Atlas hypergol purge	35 lb	
10 minutes @ 50 scfm		
Terminal box purges, controls & System bleeds	2,400 lb	
340 minutes @ 100 scfm (estimated)		
Nose fairing jettison bottle	15 lb	
1,740 in^3 @ 2,535 psig		
Umbilical boom hydraulic system charge	55 lb	
Launcher stabilization system	14 lb	
Total range countdown GN_2		3,234 lb

Abort Requirements

LH_2 vent stack purge (vehicle)	30 lb	
3 minutes @ 10 lb/min		
Atlas LO_2 dome purge	520 lb	
10 minutes @ 730 scfm		
Terminal box purges, controls & System bleeds	1,700 lb	
240 minutes @ 100 scfm		
Total abort GN_2		2,250 lb

$\underline{GN_2}$ SYSTEM, ROUTINE USE (Continued)

Usage Rate

Approximately 110 scfm (7.8 lb/minute)

Reserve Time Available

GN_2 available for holding, 9,600 - 5,484 = 4,116 lb

$$\text{Reserve time} = \frac{4,116}{7.8} \simeq \underline{\underline{530 \text{ minutes}}}$$

GN_2 SYSTEM, AIR CONDITIONING SUPPLY

Storage capacity (water volume)	17,040 ft^3	
Maximum pressure 2,400 psig, $p = 11.5\ lb/ft^3$		
Minimum pressure 600 psig, $p = 2.9\ lb/ft^3$		
(assume temperature 70° F, 530° R)		
Usable capacity = (11.5 - 2.9) 17,040 =		146,500 lb

Range Countdown Requirements

Surveyor air conditioning 96 minutes @ 78.5 lb/min	7,530 lb	
Forward compartment cooling 96 minutes @ 75 lb/min	7,200 lb	
Interstage adapter heating 96 minutes @ 160 lb/min	15,360 lb	
Atlas thrust section heating 5 minutes @ 80 lb/min	400 lb	
Atlas pod cooling 96 minutes @ 37 lb/min	3,550 lb	
Total range countdown GN_2		34,040 lb

Abort Requirements

Surveyor air conditioning 60 minutes @ 78.5 lb/min	4,710 lb	
Forward compartment cooling 60 minutes @ 75 lb/min	4,500 lb	
Interstage adapter heating (1) 240 minutes @ 160 lb/min	38,400 lb	
Atlas pod cooling 60 minutes @ 37 lb/min	2,220 lb	
Total abort GN_2		49,830 lb

Usage Rate

350.5 lb/minute (2)

(1) Figure assumes abort after T-3 seconds.

(2) The flow rate shown does not include the Atlas thrust section air conditioning. This flow will be secured in the event of a countdown delay.

GN_2 SYSTEM, AIR CONDITION SUPPLY (Continued)

Reserve Time Available

GN_2 Available for holding, 146,500 - 83,870 = 62,630 lb

$$\text{Reserve time} = \frac{62,630}{350.5} \simeq \underline{\underline{179 \text{ minutes}}}$$

GN_2 SYSTEM, HOLD-DOWN & RELEASE

Storage capacity (water volume)	50 ft^3	
Maximum pressure 8,000 psig, $p = 27\ lb/ft^3$		
Minimum pressure 6,500 psig, $p = 24.5\ lb/ft^3$		
(assume temperature 70° F, 530° R)		
Usable capacity = (27 - 24.5) 50 =		150 lb

Range Countdown Requirement

Pressurize launcher hold-down & release cylinders to 6,250 psig	12 lb

Abort Requirement

None

Usage Rate

0

Reserve Time Available

∞

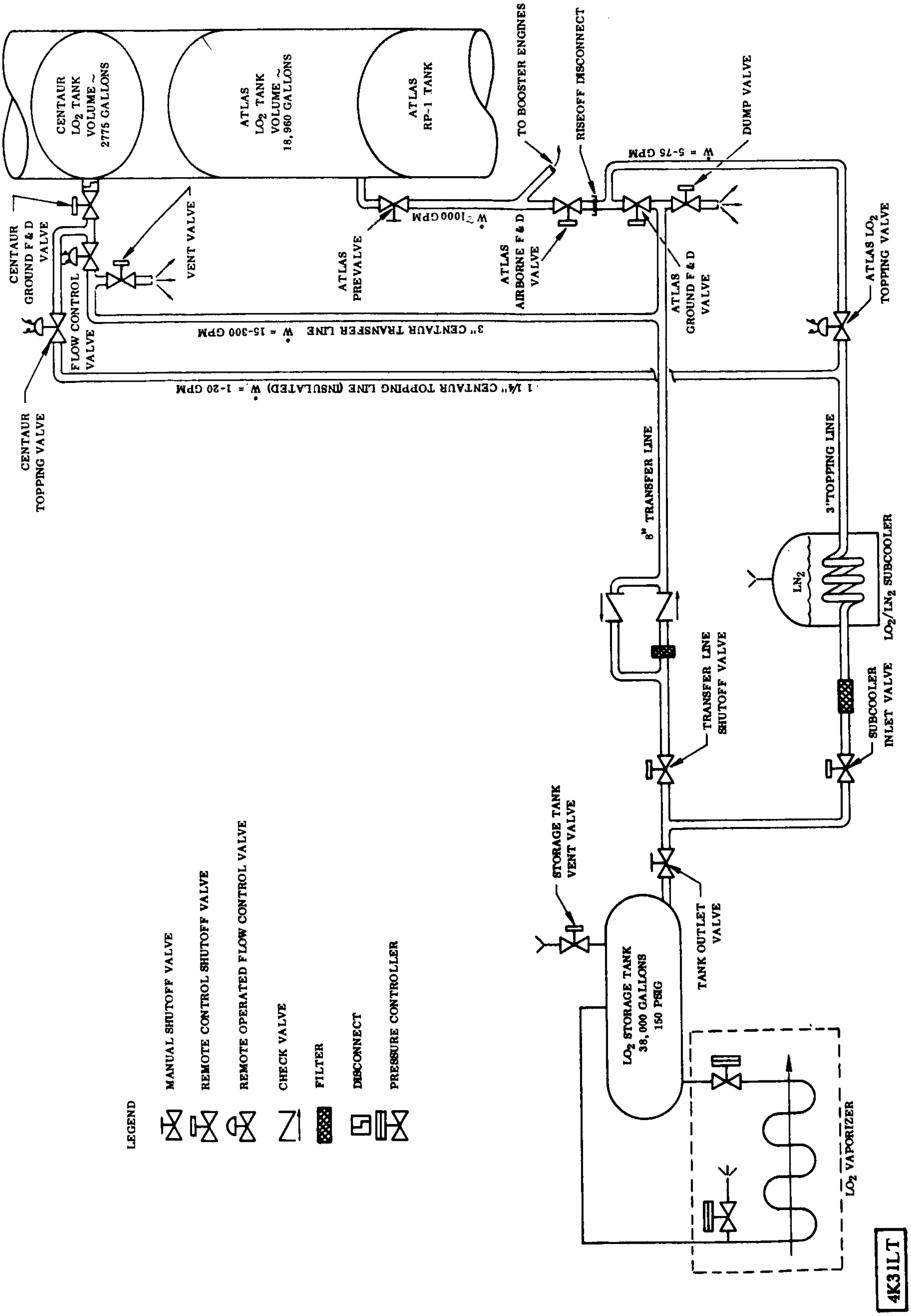


Figure B-1. Complex 36B - LO_2 Transfer System (Simplified Schematic)

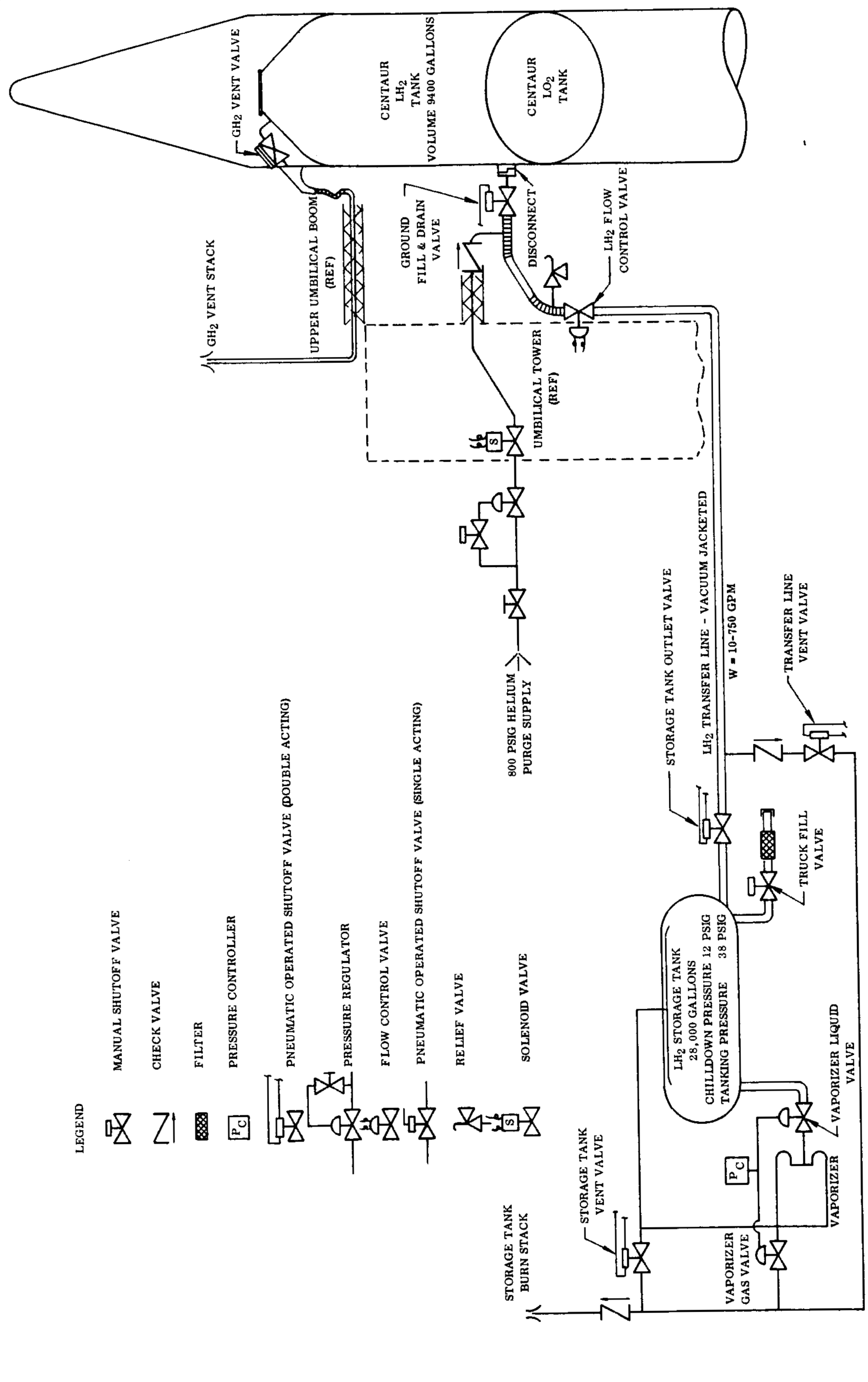


Figure B-2. Complex 36B - LH_2 Transfer Systems (Simplified Schematic)

4K32LT

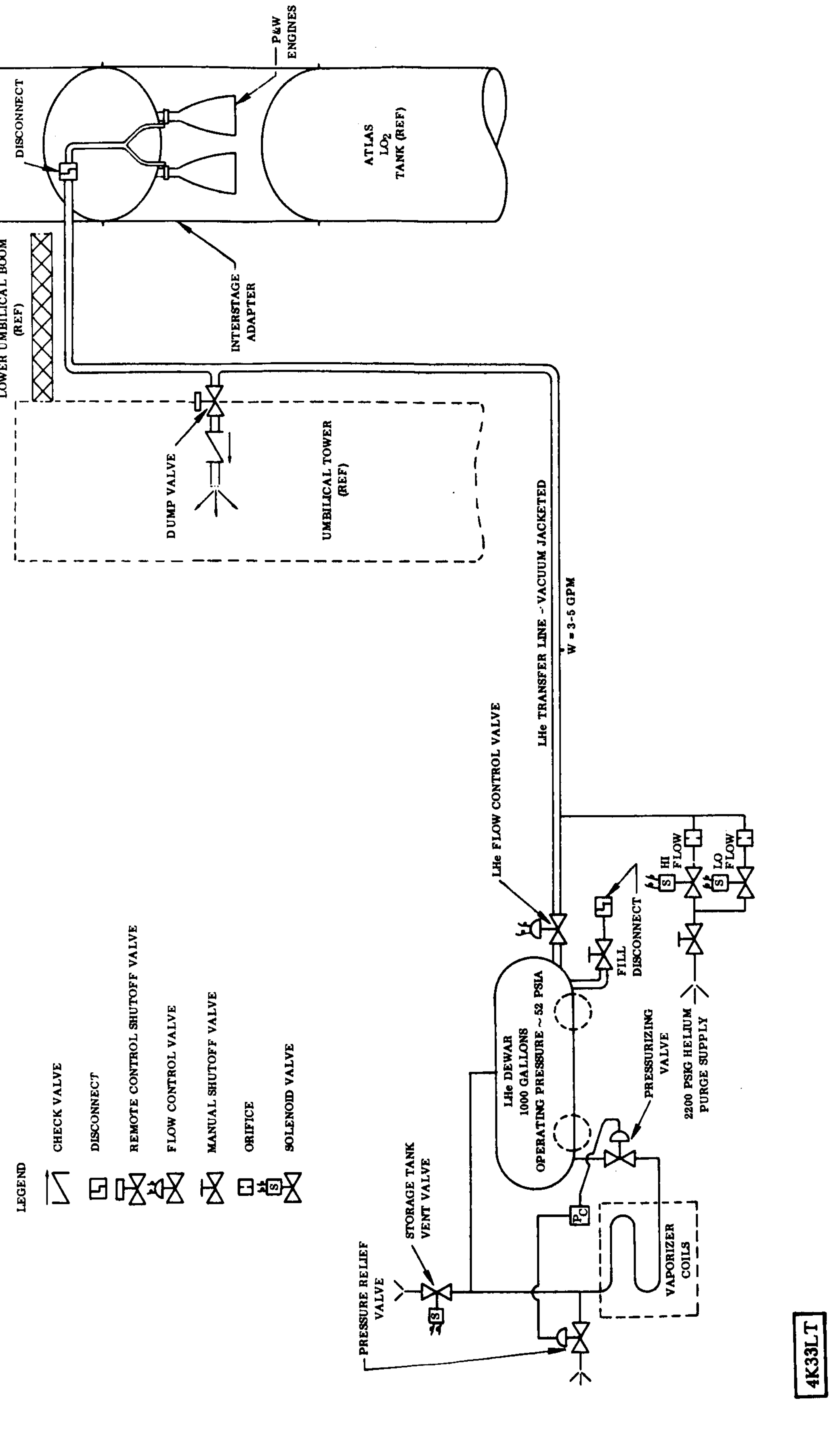


Figure B-3. Complex 36B - LHe Transfer System (Simplified Schematic)

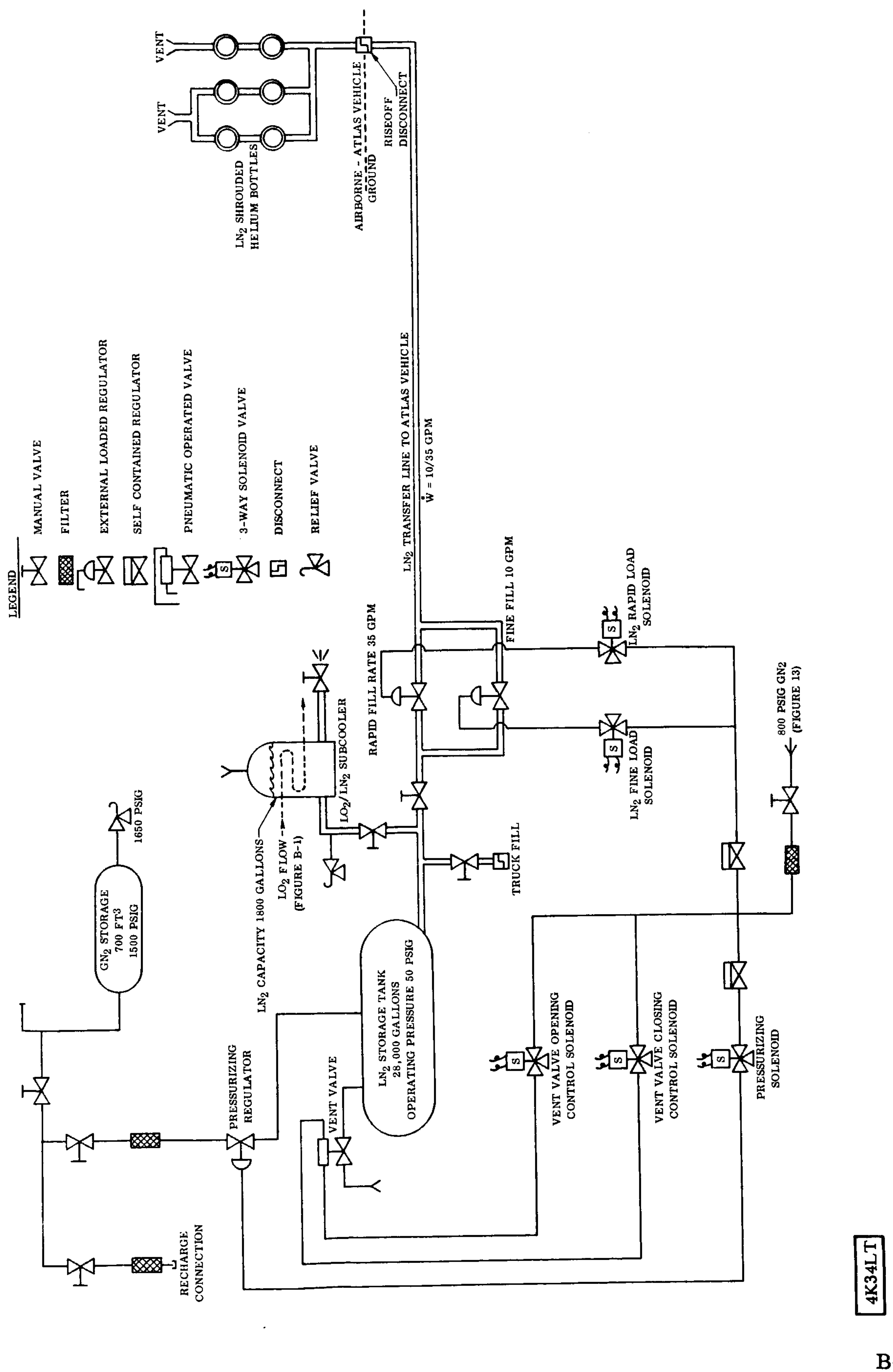


Figure B-4. Complex 36B - LN_2 System (Simplified Schematic)

4K34LT

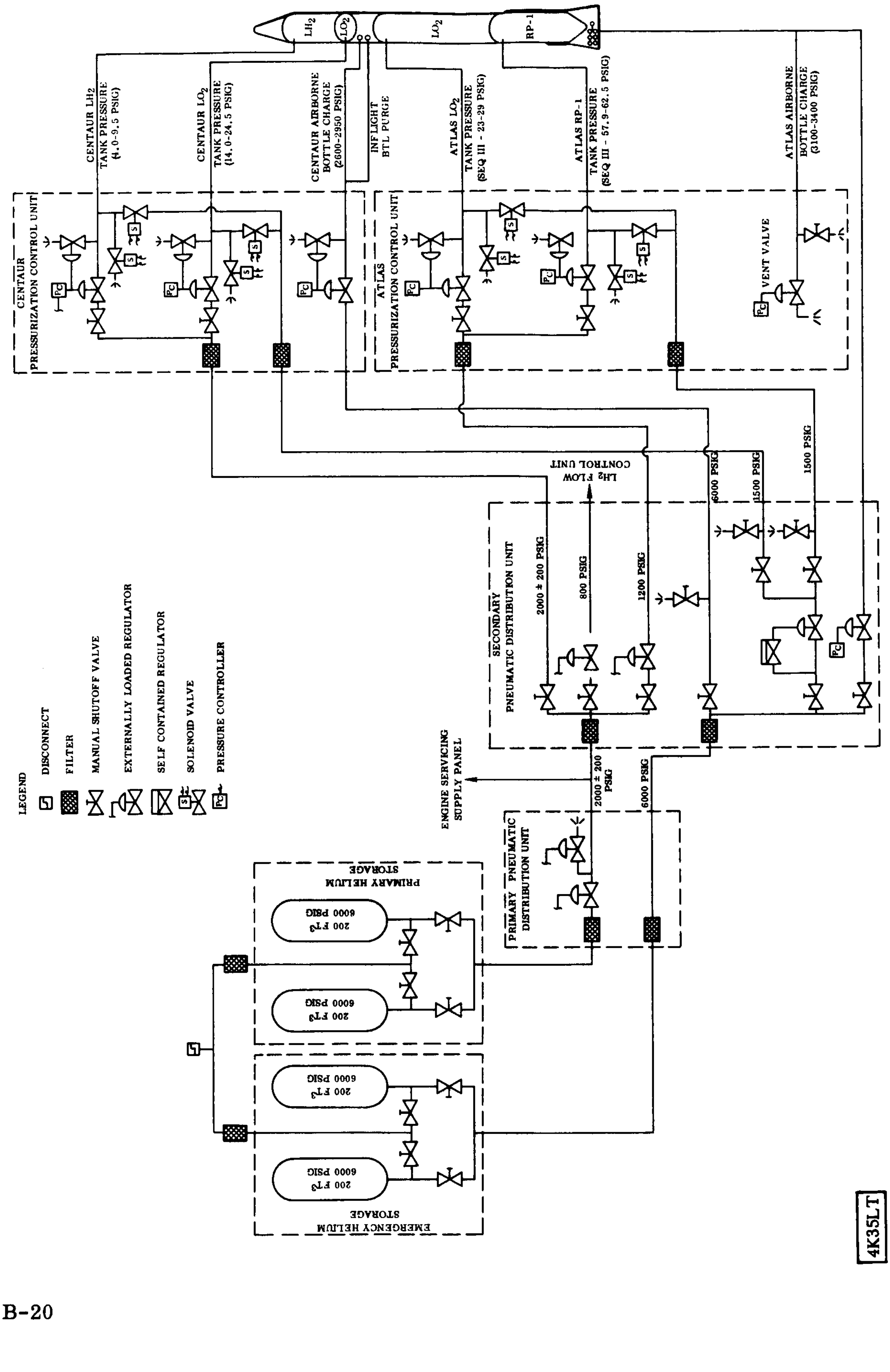


Figure B-5. Complex 36B - Helium Pressurization Supply System (Simplified Schematic)

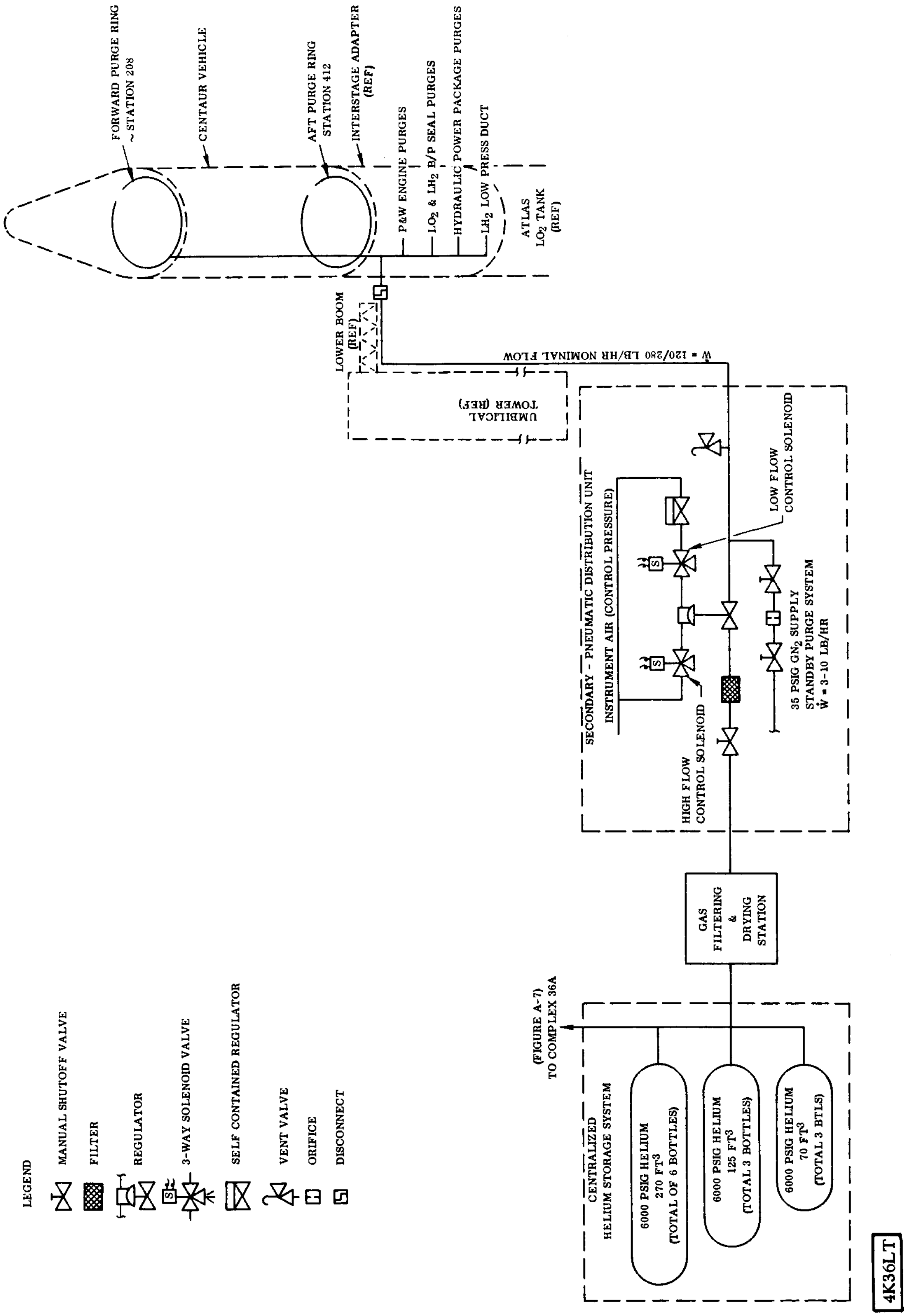


Figure B-6. Complex 36B - Insulation Panel Purge Helium System (Simplified Schematic)

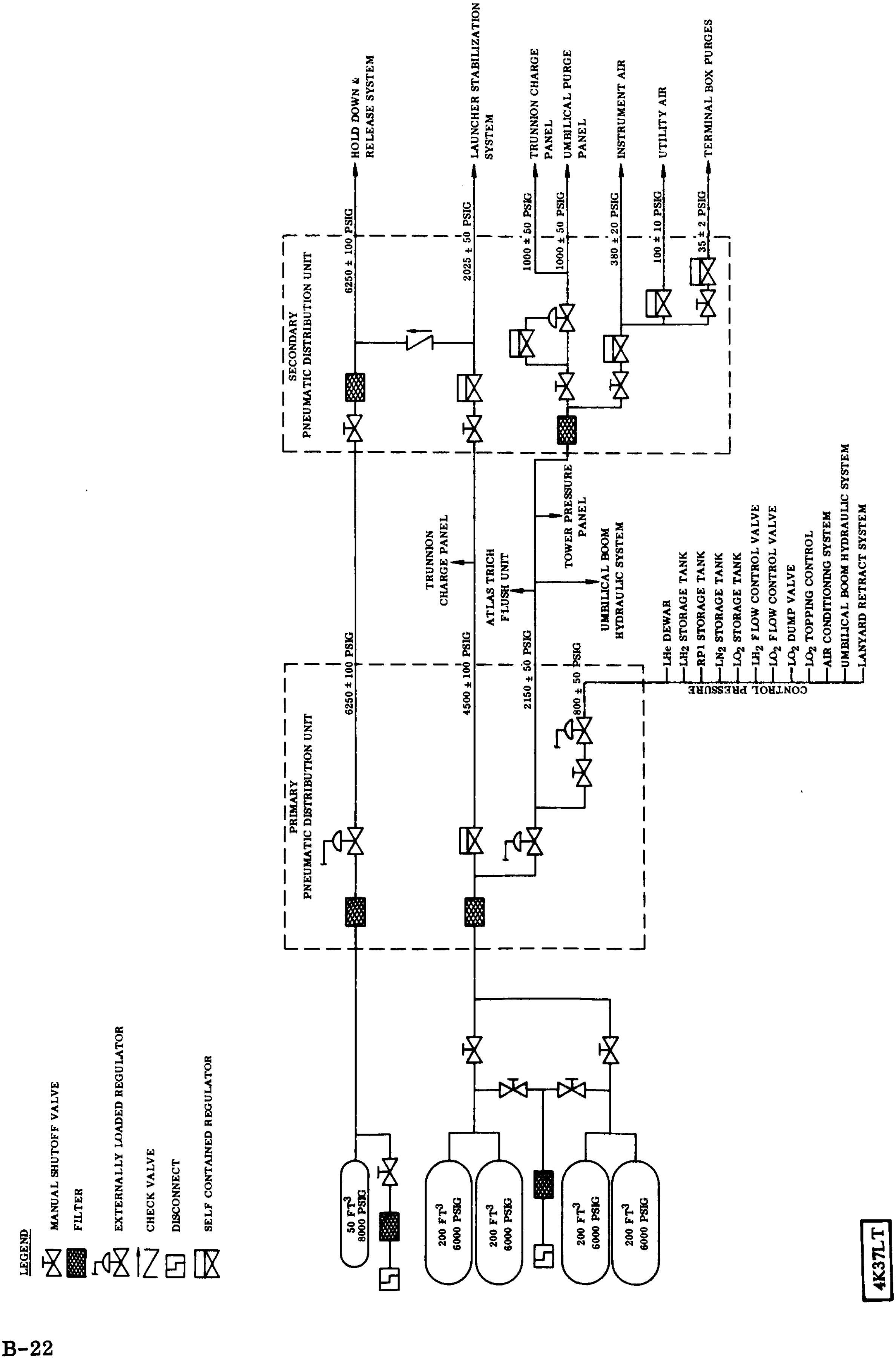
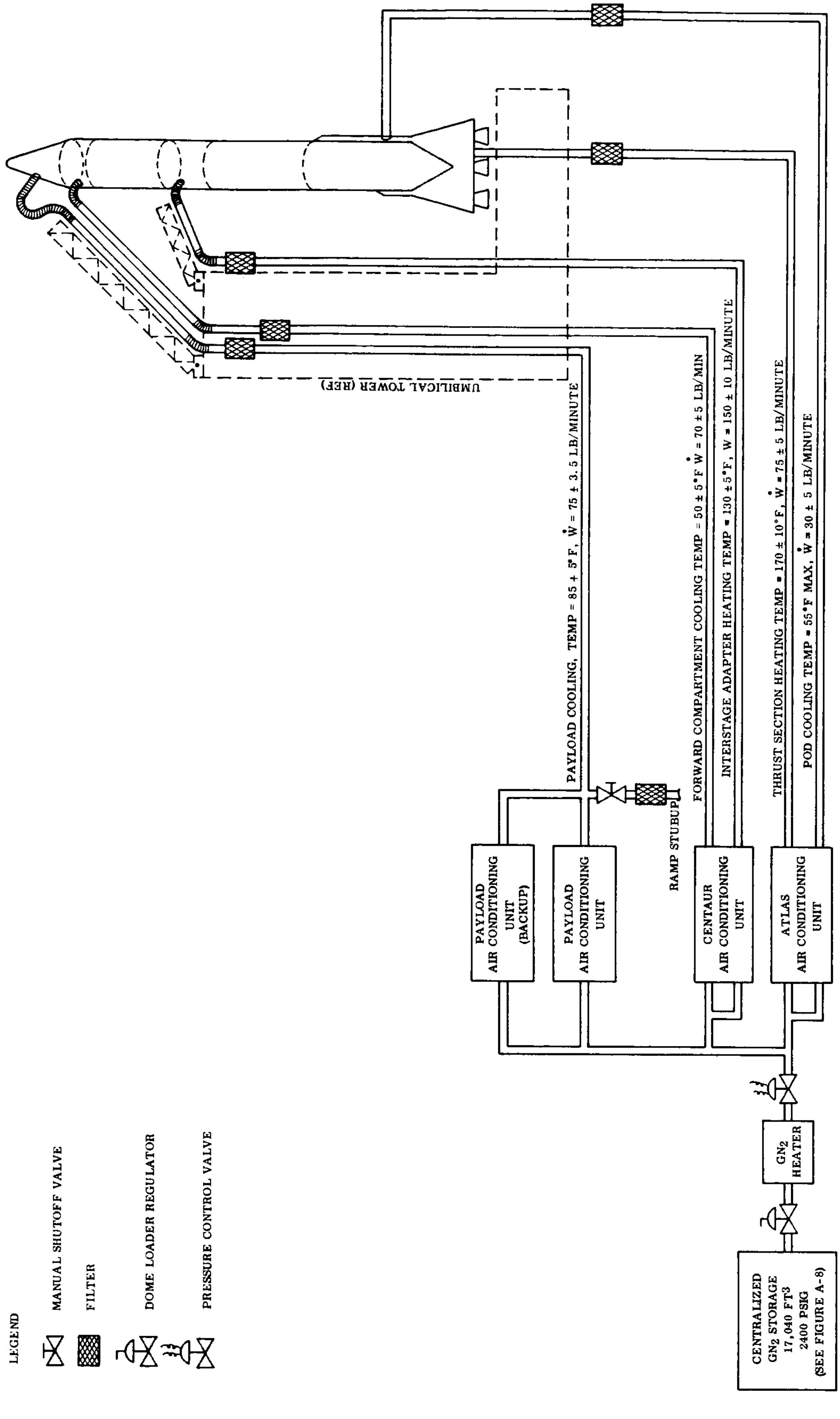


Figure B-7. Complex 36B - Routing Use GN_2 System (Simplified Schematic)



4K38LT

Figure B-8. Complex 36B - Vehicle Air Conditioning GN_2 System (Simplified Schematic)

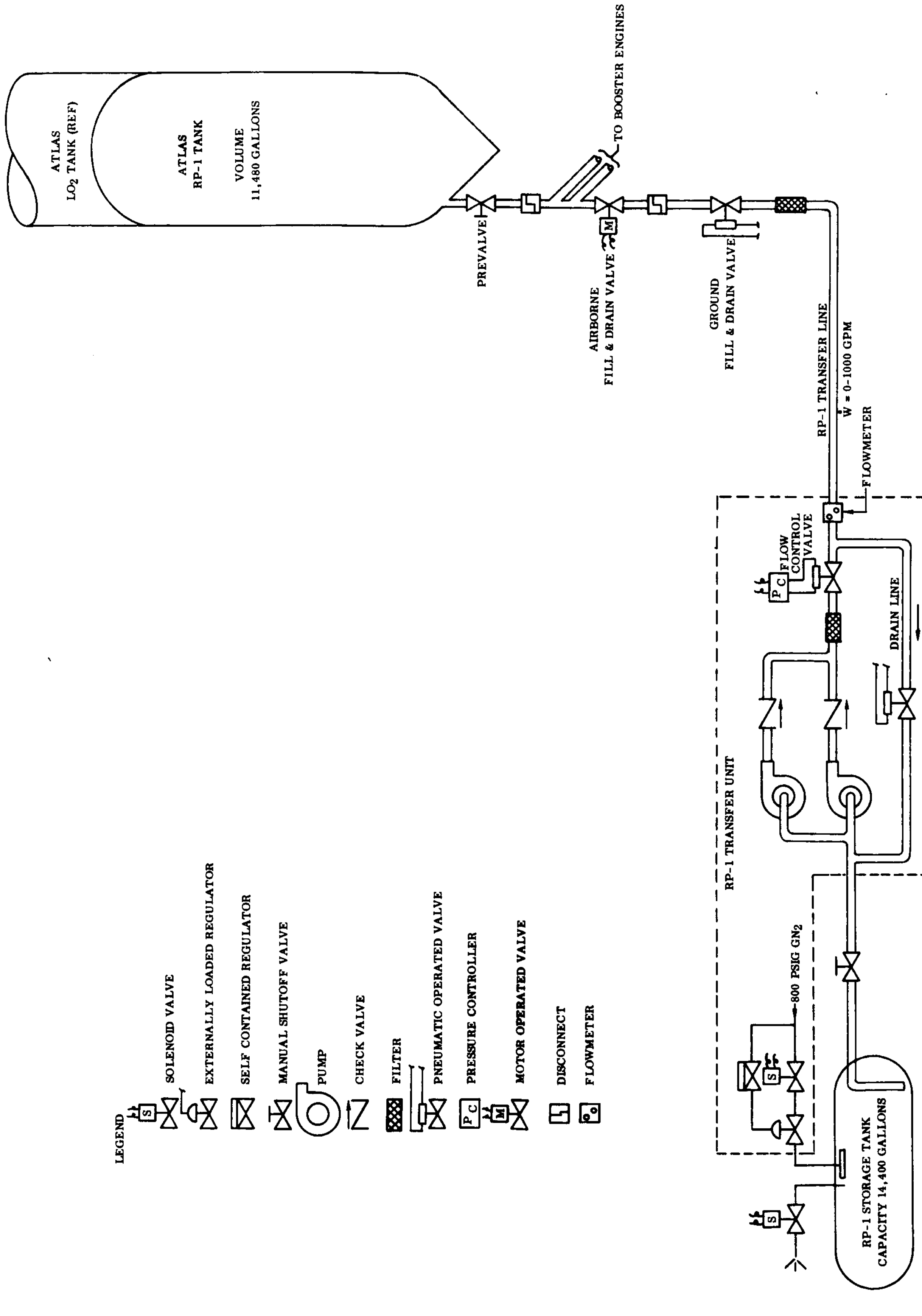


Figure B-9. Complex 36B - Atlas Fuel Transfer System (Simplified Schematic)

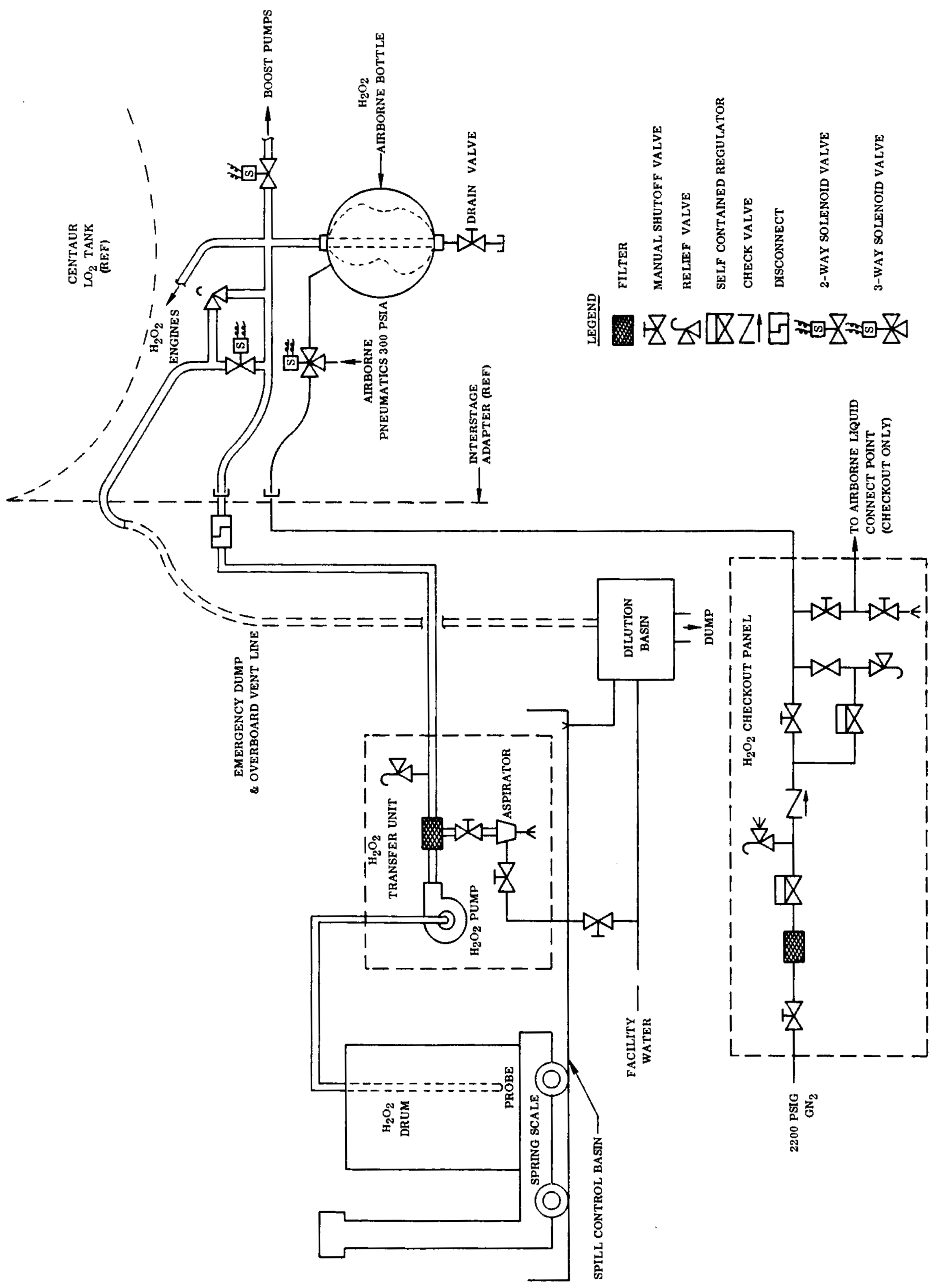


Figure B-10. Complex 36B - Hydrogen Peroxide Transfer System (Simplified Schematic)

4K40LT