HELIUM USAGE AND RECOVERY EQUIPMENT SUPPORTING DATA VOLUME III OF A DESIGN STUDY OF A HELIUM RECOVERY SYSTEM FOR MILA

John F. Kennedy Space Center
National Aeronautics and Space Administration
NASA Contract No. NAS 10-1472

Air Products and Chemicals INC.

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HELIUM USAGE AND RECOVERY EQUIPMENT

SUPPORTING DATA

VOLUME III

OF

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John F. Kennedy Space Flight Center

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Prepared by:

AIR PRODUCTS AND CHEMICALS, INC.

Allentown, Pennsylvania

FOREWORD

This report consolidates the information gathered during Phase I of the helium recovery study concerning helium usage and availability. The report includes tabulated source data, calculations, and vendors' quotations to support the conclusions presented.

The overall design study consists of three volumes:

Volume I Synopsis of a Design Study of a Helium Recovery System for MILA.

Volume II Final Report of a Design Study of a Helium Recovery System for MILA.

Volume III Helium Usage and Recovery Equipment Supporting Data

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HELIUM USAGE AND AVAILABILITY

A. GENERAL

Phase I of the helium recovery study was concerned with the amount and sources of recoverable helium at the following locations:

1. Saturn V System.

   a. Launch Complex 39 MILA*
   b. Industrial area.
   c. Various checkout buildings.

2. Saturn IB System.

   a. Launch Complex 34.
   b. Launch Complex 37.

The use of helium that have been established are:

1. Blanket gas for all LH_2 propellant tanks of the Saturn V and Saturn IB vehicles.

2. Ullage pressurization of all tanks on all Saturn V and Saturn IB stages.

3. Pressure testing of all tanks of Saturn V and Saturn IB vehicles.

4. Pressurized draining and purging of all tanks of the S-II and S-IVB stages.

5. Pressurization of control spheres for various subsystem checkouts and tests.

6. Thrust chamber purge and cooldown of S-II and S-IV stages.

7. Pressurization and purging in Apollo system checkout.

8. Regeneration of the proposed helium purification system at the converter-compressor facility of Complexes 34 and 37. (No helium purification unit is presently planned for the converter-compressor facility of Complex 39.)

9. Inerting of the LH_2 transmission fill and drain line.

*Launch Complex 39 is defined as the vehicle assembly building, compressor-converter facility, and the pad areas.

This report summarizes the data collected and revised during Phase I and lists the quantity and location of all helium used and the quantity and location of recoverable helium if economics dictate that recovery should be made.

The helium referred to throughout this report is Grade A helium. The Saturn V Apollo program also has requirements for Grade AA helium for checkout of the Apollo spacecraft. Since present information as to the availability, exact purity requirements, and uses of this grade is limited, this source of recoverable helium is excluded from the report. It appears that the quantity involved is negligible.

B. GROUND RULES AND BASIC ASSUMPTIONS

The following ground rules and basic assumptions have been established with NASA-KSC for this study:

1. A recovery system is defined as that system which captures and holds contaminated helium, purifies it to Grade A quality, and returns it to the storage facility for reuse.

2. The maximum time that contaminated helium shall remain at Cape Kennedy is 2 weeks, i.e., all contaminated helium in storage must be processed within 2 weeks after a vehicle has been processed either at the pad or the VAB. Contaminated helium is defined as all helium that has been released from storage for checkout and launch purposes, and all leakage.

3. Economics shall be based on an amortization period of 10 years and a payout period of 5 years.

4. The cost of helium shall be $3.50/lb. f.o.b. Amarillo, Texas, or $4.50/lb.* delivered at Cape Kennedy, including 15 days demurrage.

5. Cost of returning contaminated helium from Cape Kennedy to the Bureau of Mines for purification shall be 80% of that charged for shipping Grade A helium to Cape Kennedy. This helium recovery scheme will not be considered in this study.

6. Liquid helium storage or transport shall not be considered in this study. It shall be assumed that helium is delivered to Cape Kennedy in high-pressure railroad cars.

*See "Report on Long-Range Helium Transportation Optimization Study for NASA, KSC, MILA" by United States Department of the Interior, Bureau of Mines, Helium Activity for a revised cost of helium delivered at Cape Kennedy.

7. The following cost factors shall be used in this study:

   a. Power - 1.225¢/KWH
   b. Water - 10¢/1000 Gallons
   c. Plant operation labor rates:

Classification		Rate*	% Fringe Benefits
(1)	Superintendent	$ 192.70/week	20
(2)	Assistant Superintendent	161.54/week	20
(3)	Operator	3.44/hour	15
(4)	Operator Helper	3.24/hour	15
(5)	Maintenance Man	3.44/hour	15
(6)	Maintenance Helper	3.29/hour	15
(7)	Material Handler	2.57/hour	15

   d. Delivered price of cryogenic liquids and propellants to Cape Kennedy shall be as follows:

      (1) LN_2 - $ 39.50/ton
      (2) LOX - 38.25/ton
      (3) LH_2 - 1700/ton (0.85/lb.)

   e. NASA General and Administrative Rate - 10%.

   f. No interest charge is included for investment funds (cost of capital financing).

8. All helium recovery equipment within the complex shall be designed in accordance with the following (whichever is greater):

   a. Overpressure experienced during a normal launch; no allowance is included for a catastrophe.

   b. Hurricane wind velocity of 125 mph.

   c. The storage container shall be designed to sustain 75 mph winds; for hurricane winds it is contemplated that the storage containers will be deflated and covered.

9. The checkout and launch of one Saturn V Apollo vehicle will normally be performed within a 58-working-day period (one 8-hour shift per day, 5 days per week). The checkout and launch cycle for one Saturn IB is 40 days (one 8-hour shift per day, 5 days per week) at Launch

*Labor rates listed do not include fringe benefits.

Complexes 34 and 37. The checkout and launch procedure for the Saturn IB is to be identical with that of the Saturn V, except for those operations which are duplicated due to the location of the Saturn V at checkout. For example, whereas the Saturn V is pressure tested at both the VAB and the pad, only one such operation is required on the Saturn IB, since all checkout and launch operations are performed at the same location.

C. DISCUSSION

1. Saturn V.

A detailed tabulation of the helium used for each Saturn V checkout and launch operation is presented in Table I. This data was developed from the rates and quantities stated in the Saturn V Vehicle Fluid Requirements, Drawing Numbers 13M50096 (S-IC), 13M50097 (S-II), and 13M50098 (S-IVB) in conjunction with checkout sequence obtained from the various personnel at Kennedy Space Flight Center, Cape Kennedy, Florida, and Marshall Space Flight Center, Huntsville, Alabama. Appendix A shows sample contaminant calculations, and Appendix B contains a report of the personnel contacted and data obtained.

Figure 2 illustrates the weight of recoverable helium per day based on a checkout and launch sequence requiring a 58-working-day schedule.

Figure 3 illustrates the total volume of contaminated helium per day of a 58-working-day checkout and launch schedule.

2. Saturn IB.

A detailed tabulation of the helium used for each Saturn IB checkout and launch cycle is presented in Table II. This data was developed from rates and quantities stated in Saturn IB Vehicle Fluid Requirements, Drawing Numbers 13M20097 (S-IB) and 13M20098 (S-IVB). This data was used in conjunction with a checkout and launch sequence identical with that of the Saturn V vehicle, but modified by deleting one each of the identical operations performed on the Saturn V at both the VAB and pad and by substituting a checkout and launch cycle of 40 working days.

Figure 1 illustrates the weight of recoverable helium per working day based on a checkout and launch sequence requiring a 40-working-day schedule. Figure 1A illustrates the volume of recoverable contaminated helium per working day of a 40-working-day schedule.

Contaminants in the recoverable helium were calculated by the methods shown in Appendix A, Sample Calculations, and are included in Tables I and II.

D. CONCLUSIONS

1. Saturn V.

The total quantity of Grade A helium gas required for the checkout and launch of one Saturn V - Apollo space vehicle is 69,491 pounds. Of this quantity, it is feasible, though not necessarily economical, to recover 55,307 pounds. The recoverable helium is available at the following locations:

VAB	25,398 lb.
Pad	27,779 lb.
Industrial Area	630 lb.
Compressor-Converter Facility	1,500 lb.
	55,307 lb.

Of the remaining 14,184 pounds, 2,745 pounds are lost as part of the flight requirements, and 11,439 pounds are physically unrecoverable. The average composition of contaminated helium recovered from the Saturn V is as follows:

	VAB Only	Pad Only	Composition
Helium	97.4%	90.5%	93.8%
Nitrogen	2.6%	3.1%	2.8%
Hydrogen	0.0%	6.4%	3.4%
Oxygen	56 ppm	0.0%	27 ppm

2. Saturn IB.

The total quantity of Grade A helium gas required for the checkout and launch of one Saturn IB space vehicle is 16,005 pounds. Of this quantity, it is feasible to recover 12,500 pounds. All recoverable helium is obtained at pad 34 and/or pad 37, since all checkout and launch operations are performed in the pad area. Of the remaining 3,505 pounds, 950 pounds are lost as part of the flight requirements, and 2,555 pounds are unrecoverable.

The overall composition of recoverable contaminated helium associated with the Saturn IB is helium - 93.0%; nitrogen 2.3%; hydrogen 4.7%; and oxygen - 40 ppm.

E. SUPPORT DATA

Appendixes A through E contain information supporting the conclusions presented in this study, as follows:

1. Appendix A shows sample calculations used to determine helium usage and average impurities.

2. Appendix B consists of a detailed report of the cost and usage data obtained from NASA during a trip to KSC.

3. Appendix C contains letters of quotation and technical discussion from the various vendors contacted as potential suppliers of helium storage equipment. A trip report covering information obtained at Lewis Research Center is also appended.

   a. Birdair Structures, Inc.
   b. Goodyear Tire and Rubber Co., Industrial Products Division
   c. Geophysics Corporation of America, Viron Division
   d. Reeves Brothers, Inc., Vulcan Division
   e. General American Transportation Corp.
   f. Trip Report - Lewis Research Center

4. Appendix D contains letters of discussion and quotation from vendors contacted concering the helium compressor requirements.

   a. American Instrument Co., Inc.
   b. Fuller Company Division of General American Transportation Co.
   c. Rootes-Connersville

5. Appendix E consists of a listing of the documents and drawings provided by NASA concerning the vehicle launch site.

6. Appendix F lists the various commercial sources which were consulted for technical, estimating, and cost information, including the broad experience of Air Products and Chemicals, Inc.

APPENDIX A

SAMPLE CALCULATIONS

GENERAL ASSUMPTIONS

In the Vertical Assembly Building it is assumed that no limitation, other than economic, exists to the provision of piping for recovering helium from the vehicle.

On the Mobile Launch Structure no additional piping is allowed. For preliminary considerations, however, it is assumed that where necessary the RP-1 and LOX fill-drain transmission lines can be tapped. The economic feasibility of this will be determined later in this study.

1. Sample calculation for:

   Blanket pressurization.

   Vehicle checks.

   Propellant utilization calibration purge.

   Purge prior to transport.

   Calculations will be for the S-II LH_2 fuel tank, although they are typical for the other tanks. Since these operations all are performed at the VAB and since they will occur sequentially and/or concurrently, the calculated impurity level is averaged over all four operations. Specific assumptions for these operations are:

   a. Tank is initially filled with nitrogen at 0 psig pressure.

   b. A blanket pressure of 5 psig is applied every night and relieved every morning.

   c. The vent line is left open for 7 hours during each work day to maintain atmospheric pressure in the tank. This results in diffusion of air into the tank through the vent line.

   d. Only half of the helium involved in the 20 vehicle checks is recoverable. The other half is lost to the atmosphere in the process of performing the vehicle tests.

   e. The vehicle is transported to the pad with 5 psig pressure of pure helium.

   Blanket Pressurization.

   Volume of S-II LH_2 fuel tank = 38,400 ft.^{3} For 5 psig pressure every night, requires

$$V = (38{,}400)\left(\frac{5}{15}\right) = 12{,}800 \text{ SCF}$$

or $$W_{He} = (12{,}800)\left(\frac{4}{386}\right) = 133 \text{ lb.}$$

For 45 days this is

$$V_{He} = (45)\ (12{,}800) = 575{,}000 \text{ SCF}$$

$$W_{He} = (45)\ (133) = 5{,}960 \text{ lb.}$$

Add volume of N_2 initially in the tank.

$$V_{Total} = 575{,}000 + 38{,}400 = 613{,}400 \text{ SCF}$$

Vehicle Checks.

Twenty pressurizations to one-half flight ullage pressure (15 psig), or

$$W_{He} = (38{,}400)\ \left(\frac{1}{2}\right)\left(\frac{15}{15}\right)\ (20)\ \left(\frac{4}{386}\right) = 3{,}980 \text{ lb.}$$

Only 1/2 is recoverable, or

$$W_{He} = \frac{3980}{2} = 2{,}000 \text{ lb.}$$

$$V = \left(\frac{386}{4}\right)\ (2{,}000) = 193{,}000 \text{ SCF}$$

Pressurization Utilization Calibration Purge.

For a time period of 1 hour, using purge rate of item 2.17, Drawing 13M50097,

$$W_{He} = (62.7)\ (60) = 3{,}760 \text{ lb.}$$

$$V = (3{,}760)\left(\frac{386}{4}\right) = 363{,}000 \text{ SCF}$$

Purge Prior to Transport.

By item 2.17 of Drawing 13M50097,

$$\dot{W}_{He} = 3{,}260 \text{ lb.}$$

$$V_{He} = (3{,}260)\left(\frac{386}{4}\right) = 314{,}000 \text{ SCF}$$

Since transported to pad with 5 psig tankful, subtract

$$V = (38{,}400)\left(\frac{20}{15}\right) = 51{,}000 \text{ SCF}$$

Recoverable helium is

$$V_{He} = 314{,}000 - 51{,}000 = 263{,}000 \text{ SCF}$$

$$W_{He} = 263{,}000\left(\frac{4}{386}\right) = 2{,}730 \text{ lb.}$$

<u>Impurities</u>.

Initial tankful of N_2.

$$V = 38{,}400 \text{ ft.}^3$$

<u>Diffusion into open vent</u>.

This can be estimated from the general time dependent diffusion equation

$$\frac{\delta \eta_{air}}{\delta \theta} = D_{air-He}\,\frac{\delta^2 \eta_{air}}{\delta z^2}$$

Where η_{air} = moles of air

θ = time

D_{air-He} = mass diffusivity coefficient

z = length

The solution to this partial differential equation is the error integral which is plotted in McAdams, <u>Heat Transmission</u>, third edition, page 39. Using this solution, the concentration of air in helium in the vent line at the end of seven hours can be plotted. The mass diffusivity coefficient, D_{air-He}, can be estimated from equation (8-12) of Reid & Sherwood, <u>Properties of Gases and Liquids</u>.

$$D_{air-He} = \frac{.001858\, T^{3/2}\left[\dfrac{(M_{He})+(M_{air})}{(M_{He})\ (M_{air})}\right]^{1/2}}{\Sigma^2_{He-air}\,\Omega_D}$$

The values of $\Sigma_{He\text{-}air}$ and Ω_D are given in the reference. Calculation gives

$$D_{air\text{-}He} = .69 \frac{Cm^2}{Sec}$$

For a vent of constant cross section, the concentration of air in helium averages 30% in a 20 ft. length (0% beyond 20 ft.) at the end of 7 hours. Applying this result to the S-II LH_2 fuel tank (2 - 7" vent lines) gives a volume of

$$V_{air} = (.3) \frac{\Pi \; (7/12)^2}{4} (2) \; (20) \; (45) = 145 \text{ ft.}^3$$

or

$$V_{N_2} = 115 \text{ ft.}^3$$

$$V_{O_2} = 30 \text{ ft.}^3$$

Adding the 115 ft.^{3} nitrogen to the initial tankful of 38,400 ft.^{3} shows it to be negligible.

The total volume of recoverable contaminated helium is

$$\begin{array}{r} 613{,}400 \\ 193{,}000 \\ 363{,}000 \\ \underline{263{,}000} \\ 1{,}432{,}400 \end{array} \text{ ft.}^3 \text{ (approximately 14,324 lb.)}$$

Average nitrogen impurity

$$\% \; N_2 = \frac{38{,}515}{1{,}432{,}400} = 2.7\%$$

Average oxygen impurity

$$\% \; O_2 = \frac{30}{1{,}432{,}400} = 20 \text{ ppm}$$

2. Sample calculation for purge after LOX load test on S-II LH_2 fuel tank. Assume tank initially filled with hydrogen at -50°F.

$$V_{H_2} = \frac{530}{410} (38{,}400) = 49{,}600 \text{ SCF}$$

By item 2.47 of Drawing 13M50097

$$W_{He} = 2,425 \text{ lb.}$$

$$V_{He} = 2,425 \left(\frac{386}{4}\right) = 234,000 \text{ ft.}^3$$

$$V_{Total} = 283,600$$

$$\% H_2 = \frac{49,600}{283,600} = 17.5\% H_2$$

3. Sample calculation for LH_2 load test on S-II LH_2 fuel tank. There are three operations involving helium -

   a. Ullage pressurization

   b. Pressure-drain of LH_2

   c. Inerting of LH_2 tank

   From Drawing 13M50097

   a. Item 2.3

   $$W_{He} = 210 \text{ lb.}$$

   b. Item 2.30

   $$W_{He} = 2,000 \text{ lb.}$$

   c. Item 2.47

   $$W_{He} = 2,425 \text{ lb.}$$

   Total weight of helium = 4,635 lb.

   $$V_{He} = (4,635) \left(\frac{386}{4}\right) = 447,000 \text{ SCF}$$

   Impurities.

   If the assumption is made that the collection of impure helium begins at the time the liquid interface passes the point which defines the closed system to be purged, the amount of hydrogen included in the helium will be determined by boiloff and diffusion and by pockets of nondrainable liquid in the tank. Using methods similar to those in No. 1 above, the amount of hydrogen due to boiloff and diffusion is

$$W_{H_2} = 75 \text{ lb.}$$

Nondrainable liquid remains in the triangular space above the common LH_2 - LOX bulkhead and below the LH_2 fill-drain line. The dimensions are approximately 2 ft. by 10 inches right triangle on a 33 foot diameter, or

$$V = \frac{(2)\left(\frac{10}{12}\right)}{2} (33) = 86.8 \text{ ft.}^3$$

$$W_{H_2} = (87)\ (4.42) = 383 \text{ lb. } H_2$$

There are also five suction lines to the engines of 6-inch diameter and approximately 2 ft. in length which account for another 9 lbs. Thus, total H_2

$$\begin{array}{r} 75 \\ 383 \\ \underline{9} \\ 467 \text{ lb. } H_2 \end{array}$$

$$V_{H_2} = 467 \left(\frac{386}{2}\right) = 90{,}000 \text{ SCF}$$

$$V_{Total} = 537{,}000 \text{ SCF}$$

$$\%\ H_2 = \frac{90{,}000}{537{,}000} = 16.7\%$$

4. Calculations for pressurized helium bottles. For all helium bottles, the amount of gas used is obtained from the applicable items listed in Drawings 13M50096, 13M50097, and 13M50098. For miscellaneous tests at the VAB, it is assumed that the gas is pure and that only one-half of the total used is recoverable, the remainder being lost to the atmosphere during the various tests.

5. Calculation for inerting of LH_2 cross-country fill-drain line. For 10" I.D. pipe, 1,800 ft. long:

$$V = \frac{\Pi\ (10)^2}{(4)\ (144)} (1{,}800) = 980 \text{ ft.}^3$$

No reference is available to determine amount used to inert. If assumed to require less than 1% H_2, use approximately 100 volumes of helium or

$$V_{He} = (100)\ (980) = 98{,}000\ \text{ft.}^3$$

$$W_{He} = 98{,}000\ \frac{4}{380} = 1{,}000\ \text{lb.}$$

At pad 37B, this purge takes 1/2 hour. If the purge rate for the S-II LH_2 tank (26.4 lb./min.) is used, (item 2.47 of Drawing 13M50097)

$$V_{He} = (26.4)\ (30) = 800\ \text{lb.}$$

Since there is reasonable agreement between these two values, use the higher value, 1,000 lb. For the four purges which are recoverable, the line contains two volumes of hydrogen vapor at saturation conditions,

$$P = .08\ \text{lb/ft.}^3$$

$$V_{H_2} = (2)\ (.08)\ (980)\ \frac{(386)}{(2)} = 30{,}200\ \text{ft.}^3$$

$$V_{He} = (4)\ (98{,}000) = 392{,}000\ \text{ft.}^3$$

$$V_{Total} = 422{,}200\ \text{ft.}^3$$

$$\%_{H_2} = \frac{30{,}200}{422{,}200} = 7.2\%$$

APPENDIX B

Air Products and Chemicals, Inc. August 11, 1964

Trip Report of D. Kelemen, D. McGinnis, and P. Fennema
Helium Recovery Study of MILA
NASA Contract Number NAS10-1472
APCI Project No. 00-4-1165

The following summarizes the helium usage information obtained from various personnel within NASA who are directly associated with the Saturn V and Apollo Program.

This report covers the period from August 2 through 4 at Huntsville, Alabama and August 5 through August 9 at Cape Kennedy, Florida.

It should be noted that several discrepancies exist between the information obtained from the various sources. No attempt has been made to resolve these discrepancies at this time, but merely to report the data obtained.

ERRATA SHEET

TRIP REPORT

HELIUM RECOVERY STUDY FOR MILA

The below listed corrections and/or additions have been prepared for incorporation as shown into the Trip Report, dated August 11, 1964, "Helium Recovery Study for MILA".

1. Revise LN_2 price in item 1a, page B-4 to $39.50/ton.
2. Change item 3, page B-6 to read psia.
3. Add the following after first sentence of item 5, page B-6 (probably 3 to 4 times per test).
4. Revise second sentence of item 6, page B-6 to "of one shift per day normal . . . . . ".
5. Delete second sentence of item 9, page B-6 in its entirety and substitute the following sentence. "The first two purges are to inert the fuel system before and after the hydrogen load test and a third purge is to inert the fuel system after precooling the fuel tank prior to loading of LOX.
6. Substitute the word "head" for "heel" in second line of item 12, page B-6.
7. Substitute the word "spheres" for "cylinders" in first line of item 13, page B-6.
8. Delete the words "is not permissible" in item 2, page B-7 and substitute "can be avoided (by-pass)".
9. Substitute the word "helium" for "nitrogen" in item 4, page B-7.
10. Revise second sentence of item 5, page B-7 to read: "is presently "0" leakage with soap bubble test for 5 minutes per joint".
11. Change temperature of item 2a, page B-7 to read minus 320°F.
12. Change temperature of item 2e, (2), page B-7 to read 250°F.
13. Revise person contacted to read: Messrs. E. Fannin, W. Backus, J. Humphrey.
14. Add the following after the word "bottles" in item 1a, page B-9 "in LOX tank".
15. Revise second line of item 1c, page B-9 to read: ....temperatures once with RP-1 aboard and once without RP-1 aboard.

16. Substitute the word "vehicle" for "engines" in item 2a, page B-9.

17. Change second line of item 4a, page B-10 to read: ....three times to pad safety at 1000 psi.

18. Add the following at the end of the third sentence of item 4a, page B-10. (This operation may require that the bottle pressurization be performed more than once.)

19. Modify the first line of item 5, page B-10 to read as follows: The LH_2 supply line is purged before and after use . . . . . is obtained.

20. Delete table listed under item 4, page B-4 in its entirety and substitute the following:

TANK CAPACITY - WATER VOLUME $FT.^3$

STAGE	RP-1	LOX	LH_2
S-IC	29,474	47,495	
S-II		12,910	38,400
S-IVB		2,828	10,457

The S-IC RP-1 and LOX tank material is aluminum 2219-T87. The S-II LH_2 and LOX tank material is aluminum 2014-T6. The S-IVB LH2 and LOX tank material is aluminum 2014-T6 although the S-IVB tank is insulated on the inside. The type of insulating material as furnished by Douglas is unknown to the Future Studies Branch at this time.

Monday - August 3, 1964

Persons Contacted: A. R. Raffaelli, NASA
G. Bottomley, Chrysler (assigned to NASA)

General introduction and orientation.

Persons Contacted: Messrs. M. D. Beck and G. Eudy (GSE from MSFC)
Messrs. Beck and Eudy discussed their group's function and requested that they be contacted during Phase II and III of this study for the purpose of determining the compatibility of proposed recovery schemes with existing hardware.

The afternoon was spent in general discussions with Messrs. Raffaelli and Bottomley as summarized below:

1. The following delivered prices to Cape Kennedy of cryogenic propellants and liquids were stated:

   a. LN_2 - \$57/ton

   b. LOX - \$38/ton

   c. LH_2 - \$1460/ton (\$0.73/lb.)

2. The following factors to be used for this study were received:

   a. Power - 1.225¢/KWH

   b. Operation Labor - APCI to use same rates presently experienced at Patrick AFB LOX Plant.

   c. Labor Efficiency - To be determined by APCI

3. Actual helium used based on purchasing records for Saturn launches of SA-5 and SA-6 were given as

   a. SA-5 33,340 lbs. of helium

   b. SA-6 22,163 lbs. of helium

   NOTE: S-IV was operational on both vehicles

4. The following tank capacities were received:

Stage	LH_2 Tank	LOX Tank
S-II	38,400 Cu. Ft.	12,910
S-IVB	10,457	2,828

5. The following ground rules applicable to this study were discussed:

   a. At present, it is contemplated to deliver helium to Cape Kennedy in high-pressure railroad cars and not as a liquid.

   b. Equipment within the complex is required to withstand the overpressure experienced during normal launch.

   c. Only normal launch will be considered in this study although some consideration should be given to expendability of equipment in case of a catastrophe.

   d. Economics shall be based on:

      (1) Ten (10) year amortization period

      (2) Five (5) year payout period

6. The KSC Operation Plan (preliminary), consisting of several manuals, was reviewed. The following information concerning helium usage was extracted:

   a. Page 6.10.3.3 - One Saturn V checkout and launch is predicted to require 7,784,000 SCF (77,840 lb.) of helium.

   b. Page 6.10.3.4 - One Apollo checkout and launch is predicted to require 200 SCF (2 lb.) @ 6000 psig.

<u>Tuesday - August 4, 1964</u>

Person Contacted: Mr. B. H. Adams

The following information was received from Mr. Adams and associates:

1. All tanks of all stages arrive at Cape Kennedy with 3 - 5 psig nitrogen except the S-IV tank for which helium is specified.

2. Continuous helium purge of hydrogen tanks are performed using the pressurizing line as inlet and the drain line as outlet. The following data applies:

Stage	Rate	Time	Supply
S-II	62#/min	52 min	600 psig
S-IVB	20#/min	50 min	600 psig

NOTE: Venting of helium purge is expected to be accomplished through vents exiting external to the VAB.

3. Pressure test LH2 fuel tanks at following pressure:

Stage	Rate
S-II	20 - 25 psig
S-IVB	20 - 25 psig

NOTE: Full working pressure of these tanks is 40 psig.

4. One pressure test of helium spheres is performed in VAB at 1500 psig. The pressure in the spheres may not exceed 1500 psig in VAB for safety reasons.

5. The subsystem checkouts require pressurization of control spheres for approximately 12 tests at VAB. Doubt was expressed at the recovery possibility from the control spheres during these tests.

6. Allowance should be made for the additional helium usage because of one shift per week normal operation which would require that all tests be completed within an eight hour day or restarted.

7. All LH_2 fuel tanks are pressurized to 3 - 5 psig with helium prior to departure of Mobile Launch Structure with vehicle aboard from the VAB to the pad.

8. A full pressure test is performed at pad on all control spheres at design temperatures.

9. A propellant load test and two purging operations will be performed at the pad. The first purge is for inerting the fuel system after the hydrogen load test and the second purge is to inert the fuel system after precooling the fuel tank prior to loading of LOX.

   NOTE: During the load test, the fuel and oxidizer tanks will not be filled simultaneously.

10. The pressurization of the control spheres is required for two additional subsystem tests at the pad.

11. The fuel tank insulation is on the inside of the S-IVB stage and on the outside of the S-II stage. The material of the S-II fuel tank is an aluminum alloy.

12. Because of the position of the LH_2 fuel tank drain line, a two foot heel of LH_2 remains in the tank after draining.

13. Helium cylinders are presently used in the S-IVB stage to drain the LOX tanks after a cryogenic load test.

Person Contacted: Mr. N. Porter

The following information was received from Mr. Porter:

1. The helium supply lines on Mobile Launch Structure were discussed. The present design has two 3" double extra strong lines supplying helium to Mobile Launch Structure with only one line, 2.3" ID, approximately 300 ft. long, 6000 psi service, ascending the tower.

2. A capability exists to vent the helium lines at bottom of the Mobile Launch Structure. Backflow through the helium filters is not permissible.

3. The proposed procedure is to blow down the 6000-psi helium line to atmospheric pressure prior to transporting the Mobile Launch Structure back to VAB or parking area.

4. A positive pressure is then maintained in helium lines using nitrogen.

5. The estimated helium loss associated with the Mobile Launch Structure helium lines is 0.5 cc/min per fitting.

Persons Contacted: Messrs. T. White and R. Barclay

The following information was received from Messrs. White and Barclay:

1. The blowdown loss expected in each CCF helium compressor is approximately 500 SCF (5 lb.)/compressor/day. Five (5) compressors are planned for Complex 39. The contaminants are oil, air, and water.

2. Helium is to be used in regeneration of cold trap purification system. Since the design of this unit is incomplete, the following information was provided:

   a. Initial conditions:

      minus 350°F, 6000 psi

   b. Total contaminants to be based on 10-hour operation at 750 SCFM (7.5 lb.) helium containing 500 ppm impurities (80% N_2 and 20% O_2).

   c. Total volume of system

      15 CF water volume

   d. Bed volume

      3 CF water volume

   e. Proposed reactivation procedure

      (1) Depressurize bottle to 1 atm gage

      (2) Heat to 350°F in closed system bleeding excess pressure

(3) Purge and cool with pure helium till helium purity is 50 ppm

(4) Repressurize bottle to 6000 psi for standby

3. Compressors for Complex 39 are Joy Compressor having 110-125 psig suction, 6000 psig discharge (capability to 10,000 psi discharge), and 150 SCFM.

4. The replenishment rate at Complex 37 is 2 hours/day, 7 days/week. Present practice is to pump helium trailers down to 200 psig minimum thereby eliminating contamination of the tube trailers.

Wednesday - August 5, 1964

Persons Contacted: Messrs. J. B. Stone, W. Paulus, J. Jason

The following estimated quantities of helium required for each launch of the following vehicles were obtained:

Saturn I.

S-I Booster	200,000 SCF (2000 lb.)
S-IV 2nd Stage	1,970,000 SCF (19,700 lb.)

Saturn IB.

S-IB Booster	400,000 SCF (4000 lb.)
S-IVB 2nd Stage	3,940,000 SCF (39,400 lb.)

Saturn V.

S-IC Booster	2,000,000 SCF (20,000 lb.)
S-II 2nd Stage	15,760,000 SCF (157,600 lb.)
S-IVB 3rd Stage	3,940,000 SCF (39,400 lb.)

The quantities of helium required for Saturn IB and Saturn V were estimated using the following:

Saturn IB = 2 x Saturn I
Saturn V = 10 x Saturn I

The accuracy of these estimates is not known. These quantities are assumed to be order of magnitude quantities of helium for these future programs. In addition, the initial checkout of the VAB will require 18.5 million SCF (185,000 lb.) and 4 million SCF (40,000 lb.) for each launch pad.

Persons Contacted: Messrs. E. Fannin, J. Backus, R. Humphrey

The following information was obtained from this group which is associated with mechanical aspects of launch vehicle:

1. A fifty-eight day check-out and assembly schedule is assumed. During this time the LOX and LH_2 tanks of the S-II and S-IVB stages are kept under a 3 to 5 psig blanket pressure with helium. This pressure is relieved approximately 45 out of the 58 days to accommodate various tests requiring the tanks to be at atmospheric pressure. The blanket pressure of 3 to 5 psig is always applied overnight even if an operation is not completed. During this time, it is possible that an additional purge will be required following the opening of one or more tanks for inspection and/or repair. This opening of the tank is not a normal operation but has occurred in the past.

Specific information applicable to each stage is as follows:

1. S-IC Booster

   a. The helium bottles are pressurized to 1000 to 1500 psig at ambient temperature approximately 40 times for various tests at the VAB.

   b. The bottles are pressurized 3 or 4 times to 1000, 1500 psig and at ambient temperature at the pad and once to 3000 psig at cryogenic temperatures.

   c. The fuel tank is pressure tested to flight ullage pressure at ambient temperatures twice with no RP-1 aboard.

   d. The LOX tank is cycled once at the pad to flight ullage pressure with no LOX aboard, followed by pressure test to the same pressure with LOX aboard.

2. S-II 2nd Stage

   a. The LOX and LH_2 tanks are pressurized to 1/2 flight ullage pressure approximately 20 times for engine checks in VAB.

   b. The helium bottles are pressurized approximately 40 times to 1500 psig for various tests at VAB.

   c. There is a one hour purge of the LOX and LH_2 tanks to achieve -65°F dew point for the calibration of the propellant utilization (P.U.) probe. This purge is accomplished by opening fill-drain valve and purging through pressurization valve.

   d. There is a purge with grade A helium prior to moving vehicle to pad, prior to propellant load tests, and prior to loading [illegible]r flight.

   e. Purging of the external insulation on LH_2 tank is required prior to propellant load test and prior to flight.

3. S-IVB 3rd Stage

All operations are the same as those for the S-II stage with the exception of the purge of the LH_2 tank insulation which is not required on this S-IVB stage.

4. Engines

a. S-II stage has 5 engine control spheres which are purged for 5 minutes and pressurized three times to 5 psig. Venting is accomplished through the engines. These bottles are also pressurized once to approximately 600 psig for a leak check. Operating pressure is 1250 psig.

b. S-IVB stage has one engine control sphere on which the same operations are performed as for the S-II stage engine control spheres.

5. The LH_2 supply line is purged after use until a purity of better than 99% helium is obtained. This purge normally takes one half hour on pad 37B.

Thursday - August 6, 1964

Persons Contacted: Messrs. T. White, M. Hellingsworth, W. Bain

The compressor-converter facility which services Complex 34 and Complex 37 was visited. Helium is delivered to the facility in tube trailers of 40,000 SCF (400 lb.) capacity each. Helium is expanded from the initial trailer pressure of approximately 2400 psig to the compressor suction pressure of 120 psig with the pressure in the trailer tubes maintained above 200 psig minimum. The 3 Cardair compressors of 140 SCFM capacity each charge the helium to the high-pressure storage areas at each complex at a pressure of 6000 psig. Helium is lost during the initial purge of the trailer-to-compressor connecting lines, and during compressor blowdown at the end of each charging operation.

Persons Contacted: Messrs. W. R. Meyer, R. Engel, R. C. Butterworth

For the LEM fuel pressurization system, approximately 55 lbs. of helium is needed. This quantity is used three times in the industrial area for checkout operations and is loaded once on the pad for flight. The flight operating pressure is 4000 psig.

For the service and command modules 90 pounds of helium is used for the purging of the propellant tanks. These tanks also are helium pressure tested at approximately 300 psig or 1-1/2 times the 200 psig operating pressure. The fuel tank has a capacity of 2000 gallons and the oxidizer tank has a capacity of 2500 gallons. Approximately 200 pounds of helium is used in the propulsion systems checkout of the service module. This test is performed twice.

Negligible amounts of grade AA helium are used for purging the fuel cell.

Person Contacted: Mr. C. F. Brinkman

Confirmation of information received from W. R. Myers, R. Engel and R. C. Butterworth from an Industrial Area facilities standpoint. The industrial area has several 10,000 psig storage tubes only now holding helium at 6000 psig. Helium will only be used in the following five buildings of the Industrial Area:

1. Spacecraft Operation and Checkout Facility

2. Environmental Control Systems Building

3. Support Building

4. Hypergolic Test Building

5. Cryogenic Test Building

The only significant uses of helium in the industrial area are those quantities used for checkout of the Service Module and the Lunar Excursion Module.

Unrecoverable and negligible amounts will be used for welding and instrumentation checkout in the industrial area.

Person Contacted: Mr. L. S. Harris

Present plans are to equip completely only two highbays of the VAB with helium and other high-pressure gases and services. A 2" gaseous nitrogen line is the only existing vent planned; helium is to be vented directly in the building. (Design ventilation of VAB calls for one air change/hour.)

APCI was promised detail drawings of VAB plans, VAB area, and a piping flowsheet by the Future Studies Group of KSC, Huntsville.

Friday - August 7, 1964 - AM

Person Contacted: Mr. R. Burns

After initial introduction, there was a visual orientation of Complex 39, specifically the Mobile Launch Structure assembly and erection area, crawler-transport, assembly area, VAB, Launch Control Center, Compressor-Converter Facility, crawlerway, and Pad A.

Friday - August 7, 1964 - PM

The final stop was at Complex 37B for a visual orientation of an existing operational launch facility. A study was made of the type of attachments and connections commonly used for vehicle loading and of the type of ports which might be available for vent gas pick up.

APPENDIX C

BIRDAIR Structures, Inc.

BUFFALO INDUSTRIAL PARK
1800 BROADWAY
BUFFALO 12, NEW YORK

November 13, 1964

Air Products and Chemicals, Inc.
Post Office Box 538
Allentown, Pennsylvania 18105

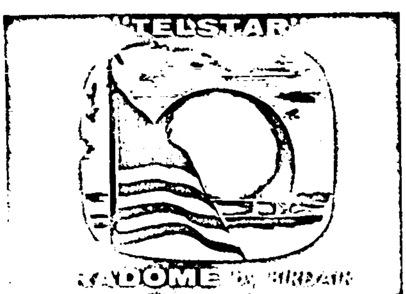
Attention: Mr. D. L. McGinnis, Cost Engineer

Gentlemen:

Please excuse the tardiness of our reply to your inquiry of 8 October 1964. The requirements themselves are difficult to understand and the solution is certainly not clear cut. We do believe, however, that there is a strong element of functional and operational feasibility. Whether the economics involved will prove favorable or not remains to be seen.

The basic concept of the flexible low pressure helium collector, as we have furnished it to NASA (Lewis Lab), consists simply of a gas tight hemispherical envelope (including floor diaphragm) constructed from a high quality Hypalon-coated nylon fabric. This envelope is in turn housed within a hemispherical air supported structure (a la radome design) of the same size and shape. A common anchorage attachment is utilized. The outer "weather shell" takes all of the inflation and aerodynamic loads, and, of course, the brunt of the exposure. Its material would be selected on the basis of the environmental requirements. Although demountable and portable, it is in a strict sense a permanent installation in that it requires a fair amount of site preparation and a good anchorage footing (in the sizes with which you are concerned).

The inner, helium collection bag is not required to resist any loading, except the pressure differential of its own weight and such buoyancy loads which result from partial filling. When fully extended by the helium, it bears against the outer weather shell. A pressure relief valve must be provided in the charge line to prevent over inflation. The helium charging and storage pressure must be equal to the inflation pressure of the outer envelope (normally 1 to 2 inches of water).



TELEPHONE: (CODE 716) 896-5100 • TWX: (CODE 716) 858-1094 • CABLE ADDRESS: BIRDAIRBUFFALO (U. S. A.)

In the original NASA unit the helium bag was only the coated fabric. This did result in slightly higher losses and contamination than was desired for their particular application. The subsequent unit (and the original, reworked) was provided with a laminate of Mylar and foil added to the inner helium bag. This significantly improved the gas-holding performance, but we, frankly, have some reservations about the overall life of the combined material (with respect to delamination) under conditions of repeated flexing. The coated fabric, foil, Mylar, and laminating cements all have different elastic characteristics and there is no long term exposure experience on the cement under these rather unique requirements.

Birdair's recommendation is that the overall system concept provide for adequate purification equipment, thus permitting the helium bag to be of the coated fabric construction only, rather than imposing a severe permeability requirement which would be exceedingly difficult to meet and even tougher to maintain. We believe this to be a realistic approach and the proper basis for evaluation.

In review of your description of the general requirements (page one of your letter), we offer the following comments:

(a) The maximum collection volume of 920,000 scf would require either one 150 ft. diameter hemispherical structure, or two 120 ft. diameter structures.

(b) The 6000 scf/minute collection rate would represent no problem.

(c) The helium collector would presumably be located remote to the tower and vehicle. We suggest that it be at least 300 ft. away to minimize launch blast and heat. The ducting of the helium collector would be the responsibility of others.

(d) As previously noted, the helium collection would normally be subjected to 1 to 2 inches of water back pressure, plus any duct friction losses. If this can not be tolerated, I presume that a pumping stage would have to be added (by others).

(e) Relative to wind velocity performance, our normal design velocity would be at 75 mph. An increase in design wind severely penalizes the design in that loading increases as the square of the velocity.

The following is in reply to your specific (page two) questions:

1. We compute that the helium permeability leakage rate from a 150' hemispherical dome would be in the order of .2 cu. ft./24 hours, or .14 cu. ft./24 hours for a 120' dome. These presume no "mechanical" leakage. Unfortunately, we can not guarantee leakage rates because we, frankly, have no means of determining or pre-testing this factor. We can offer only the assurance of "best effort" in providing a gas-tight construction. We can, of course, stop

any mechanical leak (by application of a patch) that the customer can locate and identify. We are unable to provide any meaningful indication of the inward contaminate leakage.

2. See our prior description:

   (a) As indicated, in the sizes required, the unit is essentially a fixed installation.

   (b) Flexible construction; hemispherical shape.

   (c) 1. Helium bag, Hypalon-coated nylon.

       2. Outer "weather shell," neoprene-coated nylon, Hypalon painted exterior.

   (d) The 150 ft. diameter hemispherical collector can be considered as about the upper end of the practical size range at this time.

3. With material as described above, the system could be assumed to have a life of 10 years, with the outer envelope being repainted every two to three years (based on continuous exposure).

4. There are no general "design standards," per se. The best assurance of an acceptable structure is the selection of a qualified supplier who can offer "proven performance."

5. The limit on rate of fill is mostly a function of the duct exit velocity and the resulting impingement of the gas on the envelope. Violent flapping of the fabric is to be avoided. We would normally recommend limiting the exit velocity to less than 50 ft./sec.

6. Based on the recommended configuration discussed above, in these larger size structures the cost of the helium collector system (less footings and installation) is estimated in the range of $.15 to $.20 per cu. ft.

7. See previous comments.

I hope that the above will prove helpful in your evaluation. We would, of course, be pleased to have an opportunity to be of further service if your studies indicate a basic feasibility.

Very truly yours,

BIRDAIR Structures, Inc.

Alvin C. Smith

Alvin C. Smith,
Vice President - Sales

bts

encl. (brochure, "Meet the Airshelter")

BIRDAIR Structures, Inc.

BUFFALO INDUSTRIAL PARK
1800 BROADWAY
BUFFALO 12, NEW YORK

December 23, 1964

Mr. D. L. McGinnis
Cost Engineering Department
Air Products and Chemicals, Inc.
Post Office Box 538
Allentown, Pennsylvania 18105

Dear Mr. McGinnis:

It seems that I am habitually apologizing for my tardiness in replying to your requests. This isn't a very good way of getting off on the right foot, but our proposal-quote commitments have had us working around the clock this past couple of weeks.

The following enclosures are forwarded for your presentation use:

1. Birdair Corporate Brochures (6).
2. Airshelters' promotional piece, "Meet the Airshelter" (6).
3. Two Architectural Forum article reprints (1 each).
4. Buffalo Courier Express Sunday Supplement (1).
5. Photo reproduction of our Telstar Radome, and Canadian D.O.T. Radome (6 each).
6. Material sample, typical helium collector, inner envelope (1).

The above should provide some gauge of our abilities to cope with unusual requirements and satisfy requirements for both large and unique structures. We hope that this information reaches you in time to be of use.

Very truly yours,

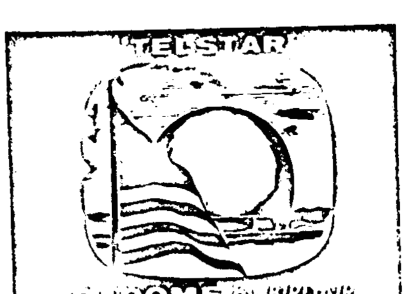
BIRDAIR Structures, Inc.

Alvin C. Smith

Alvin C. Smith,
Vice President - Sales

bts

encl.



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P.S. As requested by telcon with your Mr. Kellerman, we advise that there would be no risk of a structural rupture of the inner bag alone. It, plus the outer bag, could, of course, be ruptured by overfilling (over pressurizing). Birdair does not provide any safeguards against this beyond specifying that the customer must place a relief valve in the helium charge line, set to approximately 3-4 inches (water gage) differential. Normal inflation pressure would be in the order of 1.5 inches.

BIRDAIR Structures, Inc.

Telephone TX 6-5100

BUFFALO INDUSTRIAL PARK
1800 Broadway
Buffalo 12, New York

February 4, 1965

AIR MAIL

Air Products and Chemicals, Inc.
Post Office Box 538
Allentown, Pennsylvania 18105

Attention: Mr. D. L. McGinnis, Cost Engineer

Subject: Helium Storage Containers

Reference: (A) Your telcall January 15, 1965
(B) Birdair Letter November 13, 1964

Enclosure: (A) Two copies, Birdair Proprietary Dwg. P64-3-27
(For reference purposes only)

COPY

Dear Mr. McGinnis:

Per your request of January 15, 1965, Birdair Structures, Inc. is pleased to submit the following information and budgetary estimates for the helium storage containers as specified in the Reference (B) letter and as briefly outlined below.

We concur with you that the Birdair air supported helium gas storage container system is most suited for your application in storing large volumes of gas economically. The proposed materials will provide maximum life and will withstand the specified wind loads of 75 miles per hour.

As a matter of background information, Birdair respectfully submits that to the best of our knowledge we developed and fabricated the first flexible, air supported helium storage container in the United States. The program was accomplished for the Cornell Aeronautical Laboratories in the year 1958 and the system is still in active use. Since this initial effort, Birdair has engaged in six additional design and manufacturing programs relating to helium gas storage and salvaging operations.

The following briefly describes the system which Birdair proposes and includes such qualifications and clarifications as deemed necessary.

SYSTEM DESCRIPTION

The basic system would consist essentially of an inner and outer envelope, anchorage system, and a pressurization system.

Envelopes:

1. Inner envelope would be a hemispherical element (sizes specified below), provided with a ground diaphragm and anchorage system. The inner envelope would require bird cages to prevent the envelope from closing off the exit opening during helium deflation operations. The fabric material for the inner envelope would be Hypalon-coated nylon. Construction would utilize lap joints. The envelope would employ a roped edge pipe skirt for anchorage purposes. Suitable reinforced gas connection openings in the ground diaphragm would be provided for attachment to flanged pipes. Location of openings would be specified by the customer.

2. Outer envelope would be a hemispherical element, constructed of neoprene-coated nylon fabric with the exterior painted with white Hypalon paint. All seams would be cemented. This envelope would be provided with a roped edge pipe skirt for anchorage, in addition to a zippered flap-type personnel access door for inspection purposes. Two 8" diameter, lightweight window assembly would be provided in the outer envelope at eye level. A hooded vent would be provided in the crown area. The crown area will contain a crown plate with an eyebolt to facilitate installation, removal, inspection and repair. A service rope will be attached to the eyebolt for inspection and repair purposes. The outer envelope will be equipped with a rain skirt to facilitate water runoff and to protect the anchorage hardware.

3. Design Conditions: The proposed structure would be designed for wind loads of 75 mph.

4. Anchorage: Birdair would provide rolled pipe sections and bolts for anchoring to a concrete pad or base ring (by others). The rolled pipe anchorage system is common to both the inner and outer envelopes.

5. Pressurization System: The pressurization system would consist of two blowers with shutters to prevent back draft and motors suitable for outdoor installation. Blower controls are for indoor installation. As requested, a gasoline-powered emergency generator would not be furnished.

6. Sampling tube: Birdair would provide one tube, 3/8" diameter, of suitable plastic material, attached to the inner surface of the outer envelope, running from the inner crown of the outer envelope down to and out through the outer envelope in the vicinity of the access opening.

7. Repair Kit: Birdair would provide a fabric repair kit suitable for making minor repairs to both the inner and outer envelopes.

8. Miscellaneous: 1. Birdair would provide detailed installation, maintenance, and repair instructions.
2. Birdair would provide all necessary design and engineering liaison relative to the Birdair offering.

9. Installation: Birdair would provide the services of one factory representative to supervise the installation. The estimated manpower and equipment required (by others) for the installation appears in a later section of this proposal.

The following lists the minimum volumes of helium to be stored, the number and sizes of hemispherical containers proposed for this budgetary quotation, and the total volume enclosed by the proposed units:

Item	Volume of Gas To Be Stored (in cu. ft.)	Proposed No. of Helium Systems	Spherical Diameter	Total Volume (in cu. ft.)
1.	1,150,000	2	130'	1,150,350
2.	2,810,000	4	140'	2,873,510
3.	3,510,000	4	150'	3,534,300
4.	5,850,000	1	130')	
		6	150')	5,876,625

Estimated Budgetary Prices (FOB Cape Kennedy, Florida)

1.	Two	130' diameter systems	$200,000
2.	Four	140' diameter systems	450,000
3.	Four	150' diameter systems	510,000
4.	One	130' diameter systems and	
	Six	150' diameter systems	855,000

Delivery

Since the fabric materials to be used in the above envelopes are specially designed for this application, and since firm delivery promises were not obtained from our suppliers at this time, we can only estimate at present that the delivery of the first unit would be approximately 20-24 weeks A.R.O. with each additional unit delivered approximately 3-4 weeks thereafter.

ADDITIONAL INFORMATION

The following information is submitted to assist you in planning and budgeting for the concrete foundation installation, and the initial installation of the helium storage system:

A. Foundation Requirements: A concrete curb is required with a cross section of 8 square feet. The curbing should be rod reinforced to prevent any spreading in the event of cracks in the concrete. The inner diameter area should be completely covered with a fine grain sand, black top, or concrete, to prevent abrasion of the inner envelope ground diaphragm.

B. Installation Equipment and Manpower Requirements: To accomplish the initial installation (under Birdair supervision), it is estimated that the following equipment and manpower (to be furnished by others) would be necessary, per unit:

Laborers: 8 men for 3 days	- 24 man days
Electrician: 1 man for 2 days	- 2 man days
1 Crane - 100'-125' boom with operator (30 ton)	- 2 days on site
1 Forklift truck	- 3 days on site

We trust the information contained herein is complete and satisfactory in every respect and contains all the information you requested; also, that your customer will decide favorably in the use of this system. If you have any further questions or require further assistance, please do not hesitate to contact us.

Very truly yours,

BIRDAIR Structures, Inc.

Armand N. DeMarchi, Sales Engineer

bts

September 15, 1964

Mr. A. F. Fields
Department 722
Industrial Products Division
Goodyear Tire & Rubber Co.
Akron 16, Ohio

Dear Mr. Fields:

This is a confirmation of our telephone conversation of 9/15/64 concerning the use of Viron products as possible gas storage containers for recovered helium with small quantities of nitrogen, oxygen and hydrogen present. The helium will be recoverdd from various preparatory operations performed on the Saturn V launch vehicles at seven separate locations contained within a rough square four miles on a side.

A collection and/or storage capability of 60,000 lb, or 6,000,000 scf over a period of two weeks is required. The maximum amount collected would be 920,000 scf per one working day at one location. The minimum amount collected would be less than 50,000 scf per one working day over a 45 day period.

Exact collection rates vary but the maximum rate is approximately 6000 scf/minute.

The main restriction placed on this recovery system is that no new or additional equipment is to be added to the operational structures. Others are that the recovery equipment is not to interfere in any way with the launch preparation operations. All recovery operations are to be performed such that no back pressure is placed on the source of the helium.

A design condition is that the storage equipment be designed to withstand winds of hurricane force (125 mph or .28psi).

At this time, we request the following information from you:

1) Storage container leakage and diffusion rates - helium out and contaminants in
2) Type (s) of storage structure (s) recommended
   a) fixed or mobile
   b) rigid, semi-rigid or free-form
   c) materials of construction
   d) practical size limits and empty weights

At this time, we request the following information from you:

1) Storage container leakage and diffusion rates - helium out and contaminants in

2) Type (s) of storage structure (s) recommended

   a) fixed or mobile
   b) rigid, semi-rigid or free - form
   c) materials of construction
   d) practical size limits and empty weights

3) Life expectancy and under what conditions of use and maintenance.

4) Design standards recommended for storage of this type (s).

5) Practical limits on rate of fill for this particular type (s) of storage.

6) Approximate cost of storage of this type (s) per some unit size.

7) Limitations if any of this type (s) of storage.

The normal means of storage - compressing the gas into tubes - is not practical in this instance because the high rates of supply at different locations would necessitate several large compressors which would be too expensive to be used intermittently.

Very truly yours,

AIR PRODUCTS AND CHEMICALS, INC.

Daniel L. McGinnis
Cost Engineer
Economic Evaluation

DLM/rg

GOODYEAR

The Goodyear Tire & Rubber Company

2750 N. BROAD ST.
PHILADELPHIA 32. PA.

[illegible]r 15, 1964

Air Products & Chemicals, Inc.
P. O. Box 538
Allentown, Penna.

Attn: Mr. D. L. McGinnis, Cost Engr., Economical Evaluation

Subj: Helium Storage Domes

Gentlemen:

With reference to your letter and telephone conversation with our Akron, Plant, we are pleased to submit a suggested design and cost estimate, based on a 2 million cubic foot and a 1 million cubic foot dome.

Attached are copies of Goodyear dwg. 3065-769 which is a 100 ft. diameter Helium Storage Dome capable of storing approximately 2 million cubic feet. A 1 million cubic foot Dome would be approximately 80 ft. in diameter.

We estimate cost as follows:

Size	First Unit	2 or more Units
500,000 ~~1 million~~ S.C.F.	$ 80,355.00 16¢/scf	$ 61,488.00 each 12¢/scf
1 mm ~~2 million~~ S.C.F.	100,105.00 10¢/scf	82,590.00 each 8¢/scf

Terms: Net 10th. Proximo, FOB Rockmart, Georgia. This estimate is subject to the terms and conditions attached.

We propose to furnish 2 concentric bags with air chamber between which is pressurized to approx. .28 psi, depending on wind conditions. Thus the outer bag will remain fully inflated at all times, acting as a weather shield for the inner bag which will rise or fall, depending on the air pressure in the chamber and the amount of helium in the inner bag.

Each 100 ft. dia. dome would contain about 2 million S.C.F. We would construct the outer bag from a material similar to that used in our Radomes. The tensile strength of this outer bag will be 350x350 lbs. per sq. inch and the material will weigh approximately 33 ozs. per sq. yd. The inner bag material will have a tensile of 350x315 lbs. per sq. inch and will weigh approximately 31.1 oz. per sq. yard.

125 [illegible]

November 15, 1964

We expect the diffusion rate, based on testing with hydrogen, to be less than 0.1 liter per sq. meter in 24 hours at 1.0 inches water pressure.

No clamping bars, blowers or other hardware is included in this estimate. Supervision will be furnished through the erection and test sequences. A crane, furnished by you, will be required at the erection site. Each inner bag will be checked for leaks and pinholes after erection. Before leaving our plant, each bag will be erected for over-pressure tests to assure the structural integrity of the bag.

If you have any further question or require information of any sort, please do not hesitate to contact me at:

Goodyear Tire and Rubber Co.
P. O. Box 1037
Allentown, Penna.

Phone: 264-3029

We wish to thank you for your interest and hope we may be of service to you.

Yours very truly,

D G Roney Jr

Field Representative,
Industrial Products Div.

D. G. Roney Jr.

G-403 (7-59)

THE GOODYEAR TIRE & RUBBER COMPANY
INDUSTRIAL PRODUCTS DIVISION

Quotation Provisions

1. Price lists and quotations are subject to change without notice. Prices in accepted orders are also subject to change by Goodyear, but the Customer will be notified of any price increase and may cancel any undelivered portion of the order by written notice to Goodyear delivered not more than 10 days after notification of the increase. Upon cancellation, the Customer shall have no liability for the canceled portion of the order except as to goods then manufactured or in process, componenets procured by Goodyear from outside sources, and special tooling and equipment procured for performance of the order.

2. In addition, all prices are subject to increase from time to time to compensate for any tax, excise or levy imposed upon the goods sold, or upon the manufacture, sale, transportation or delivery of them, or whenever any tax, excise, levy, law or governmental regulation has the effect, directly or indirectly, of increasing the cost of manufacture, sale or delivery.

3. Goodyear shall not be liable or deemed in default for failure to deliver or delay in delivery due to any cause beyond its reasonable control. If unable to meet delivery schedules, Goodyear will endeavor to allocate material fairly among its customers, but reserves to itself final determination of the deliveries to be made.

4. All orders, contracts, specifications and product constructions are subject to such changes as may be required in order to comply with any applicable law or Government order, regulation or restriction.

5. Goodyear merchandise is sold subject to any standard Warranty in effect with respect to it at the time the merchandise is shipped. Goodyear warrants that all such merchandise sold as first-grade material will confirm to specifications and will be free from defects in material or workmanship. Material claimed to be defective shall be returned by the customer at its expense for inspection if Goodyear so requests. Goodyear will make an adjustment for material it finds to be defective by repairing it, by replacement at an adjustment price, or by other suitable allowance. Material sold as other than first-grade material is sold without warranty.

   Goodyear responsibility under any applicable warranty and otherwise is limited to repair or replacement of defective material, and its liability is limited to the original purchase price of the article. There is no other warranty or liability, express or implied, applicable to Goodyear Products; no representative has authority to make any representation, promise or agreement except as stated herein.

6. Goodyear will indemnify its customers against all claims, demands and liability for any alleged or actual infringement of any patent by the material or articles furnished under any accepted order provided the Customer notifies Goodyear of any alleged patent infringement and upon request tenders Goodyear the defense of the claim or suit.

GOODYEAR

The Goodyear Tire & Rubber Company

2750 N. BROAD ST.
PHILADELPHIA 32, PA.

December 29, 1964

Air Products & Chemicals, Inc.
P. O. Box 538
Allentown, Penna.

Attn: Mr. D. L. McGinnis, Cost Engr., Economical Evaluation

Subj: Helium Storage Domes

Gentlemen:

With reference to our conversations, we are pleased to submit a suggested design and cost estimate, as follows:

These are estimated figures to be used as budgetary prices. Estimates include inflation equipment, automatic controls, installation costs and hold down anals. We are quoting on 100 ft. diameter domes with a 75 ft. base diameter, which will contain approximately 500,000 cubic ft of helium. This unit is shown on the attached dwg. 3065-769A dtd. 12-16-64. Five units would be required for each 2.5 million cubic ft. site.

An inflation system would be supplied with a 2 stage pressure system working from an anometer automatically. An inflation system would also contain a standby blower and provisions for an auxiliary power source to be supplied by the base facility. It is estimated that one building approximately 20' x 20' x 8' would house the inflation equipment for two 500,000 cu. ft. units. The underground pipe for inflation should be 12" Id with 2 required per dome.

The following budgetary cost is projected based on hypalon on nylon exterior bag (2 ply) and a single ply neoprene on nylon inner bag. These estimates do not include the concrete base or anchor bolts.

Item	Cost
100 ft dia. unit	$ 102,168.00 each
Inflation equipment	4,780.50 each
Erection Frame (one only)	2,731.76 each
Erection Supervision	1,365.88 each unit
Maintenance inspection (2½ yr basis)	1,365.88 each unit
Recoating with hypalon (5 hr basis)	4,097.65 each unit

These figures are based on a minimum production order of 5 units, which would be the number needed for 1 launching area. The initial unit (1 dome) would be delivered 6 months after receipt of the order and 1 unit each month thereafter.

For erection, we would require an erection ring and a 150 ft. crane. We will furnish the erection ring which can be used on all units and also the technical supervision. A rigging crew of 12 to 15 men and the crane would be furnished by the base facility. We estimate the inner bag can be unrolled bolted down, inflated and inspected in 4 hours. The outer cover would require 8 hours by using the erection hoop and crane.

In order to insure the 10 yr service life, we recommend an inspection every 2½ years and a recoat of hypalon paint each 5 years.

Our engineering is based on the fact that the units must be automatically maintained for a period of 10 to 21 days while the rockets are fueled as no personnel will be allowed in the launch area. The usefull life of the containers requested is 10 years, based on 6 cycles minimum and 24 cycles maximum per year.

The wind velocity discussed was up to 100 mph and these containers are satisfactory. It was agreed that in winds of over 100 mph the units would be deflated and tied down with cargo nets.

We discussed the possibility of utilizing a portable unit such as an airship. The design and construction costs are prohibitive, being approx. 5 million dolloars for the project.

While we have not built domes for this specific use, we are confident our experience over the many years, building airships for the government and commercial use, all utilizing helium, plus the governments use of our Radomes, makes our proposal a practical solution for your requirements.

Terms: Net 10th. Proximo, FOB Rockmart, Georgia. This estimate is subject to the terms and conditions attached.

Photographs of our Radome installations will be forwarded under seperate cover to you by Friday, Jan. 1, 1965

Yours very truly,

Field Representative,
Industrial Products Div.

D. G. Roney Jr.

G-403 (7-59)

THE GOODYEAR TIRE & RUBBER COMPANY
INDUSTRIAL PRODUCTS DIVISION

Quotation Provisions

1. Price lists and quotations are subject to change without notice. Prices in accepted orders are also subject to change by Goodyear, but the Customer will be notified of any price increase and may cancel any undelivered portion of the order by written notice to Goodyear delivered not more than 10 days after notification of the increase. Upon cancellation, the Customer shall have no liability for the canceled portion of the order except as to goods than manufactured or in process, components procured by Goodyear from outside sources, and special tooling and equipment procured for performance of the order.

2. In addition, all prices are subject to increase from time to time to compensate for any tax, excise or levy imposed upon the goods sold, or upon the manufacture, sale, transportation or delivery of them, or whenever any tax, excise, levy, law or governmental regulation has the effect, directly or indirectly, of increasing the cost of manufacture, sale or delivery.

3. Goodyear shall not be liable or deemed in default for failure to deliver or delay in delivery due to any cause beyond its reasonable control. If unable to meet delivery schedules, Goodyear will endeavor to allocate material fairly among its customers, but reserves to itself final determination of the deliveries to be made.

4. All orders, contracts, specifications and product constructions are subject to such changes as may be required in order to comply with any applicable law or Government order, regulation or restriction.

5. Goodyear merchandise is sold subject to any standard Warranty in effect with respect to it at the time the merchandise is shipped. Goodyear warrants that all such merchandise sold as first-grade material will conform to specifications and will be free from defects in material or workmanship. Material claimed to be defective shall be returned by the customer at its expense for inspection if Goodyear so requests. Goodyear will make an adjustment for material it finds to be defective by repairing it, by replacement at an adjustment price, or by other suitable allowance. Material sold as other than first-grade material is sold without warranty.

   Goodyear responsibility under any applicable warranty and otherwise is limited to repair or replacement of defective material, and its liability is limited to the original purchase price of the article. There is no other warranty or liability, express or implied, applicable to Goodyear Products; no representative has authority to make any representation, promise or agreement except as stated herein.

6. Goodyear will indemnify its customers against all claims, demands and liability for any alleged or actual infringement of any patent by the material or articles furnished under any accepted order provided the Customer notifies Goodyear of any alleged patent infringement and upon request tenders Goodyear the defense of the claim or suit.

September 15, 1964

Mr. J. A. Menke
Viron Division
Geophysics Corporation of America
Char-Gale Building
Anoka, Minnesota 55303

Dear Mr. Menke:

This is a confirmation of our telephone conversation of 9/15/64 concerning the use of Viron products as possible gas storage containers for recovered helium with small quantities of nitrogen, oxygen and hydrogen present. The helium will be recoverdd from various preparatory operations performed on the Saturn V launch vehicles at seven separate locations contained within a rough square four miles on a side.

A collection and/or storage capability of 60,000 lb. or 6,000,000 scf over a period of two weeks is required. The maximum amount collected would be 920,000 scf per one woeking day at one location. The minimum amount collected would be less than 50,000 scf per one working day over a 45 day period.

Exact collection rates vary but the maximum rate is approximately 6000 scf/minute.

The main restriction placed on this recovery system is that no new or additional equipment is to be added to the operational structures. Others are that the recovery equipment is not to interfere in any way with the launch preparation operations. All recovery operations are to be performed such that no back pressure is placed on the source of the helium.

A design condition is that the storage equipment be designed to withstand winds of hurricane force (125 mph or .28psi).

At this time, we request the following information from you:

1) Storage container leakage and diffusion rates - helium out and contaminants in
2) Type (s) of storage structure (s) recommended
   a) fixed or mobile
   b) rigid, semi-rigid or free-form
   c) materials of construction
   d) practical size limits and empty weights

3) Life expectancy and under what conditions of use and maintenance.
4) Design standards recommended for storage of this type (s).
5) Practical limits or rate of fill for this particular type (s) of storage.
6) Approximate cost of storage of this type (s) per some unit size.
7) Limitations if any of this type (s) of storage.

As stated during our conversation, the normal means of storage - compressing the gas into tubes - is not practical in this instance because the high rates of supply at different locations would necessitate several large compressors which would be too expensive to be used intermittently.

Very truly yours,

AIR PRODUCTS AND CHEMICALS, INC.

D. L. McGinnis

Daniel L. McGinnis
Cost Engineer
Economic Evaluation

DLM:amp

VIRON

A DIVISION OF GEOPHYSICS CORPORATION OF AMERICA / CHAR-GALE BUILDING, ANOKA, MINNESOTA 55303
AREA CODE 612-421-6960

October 9, 1964

Mr. Daniel L. McGinnis
Air Products and Chemicals, Inc.
Allentown, Pennsylvania

Dear Mr. McGinnis:

This letter is in reply to your inquiry to James Menke dated September 15, 1964, concerning gas storage containers for recovered helium in connection with the Saturn V launch vehicles.

DESCRIPTION OF STORAGE CONTAINER

The type of storage container we recommend is an inflatable structure having the shape of a half-cylinder with quarter-spherical ends. It is essentially a two compartment structure separated by a flexible wall which permits either compartment to expand to assume any portion of the total volume of the container. One compartment is for storage of helium while the other serves as a variable displacement air chamber to maintain pressure on the outer envelope thereby sustaining the external shape of the container. A pressure activated relief valve and blower combination is incorporated in the air chamber to transfer air into or out of the air chamber to compensate for the transferred helium.

The structure is anchored in position by a base anchoring system around the perimeter of the container. The anchor system consists of a concrete footing to which the base of the structure is firmly attached.

Due to a combination of structural and practical limits of size, a number of containers of a limiting size is required to provide a storage capability of 6,000,000 scf. The containers are connected to a common manifold. A blower and plenum arrangement transfers the helium from the source to the manifold and maintains a condition of no back pressure on the source.

STORAGE CONTAINER PARAMETERS

a. Material of Construction - urethane coated nylon fabric.

1.	Main envelope	32 oz. per sq. yd.
2.	Floor	16 oz. per sq. yd.
3.	Inner compartment	8 oz. per sq. yd.

STORAGE CONTAINER PARAMETERS (Cont'd)

b. Size

1.	Width	92 feet
2.	Total length	212 feet
3.	Volume	600,000 $feet^3$

c. Total weight of Inflatable Container - 12,000 lbs. (approx.)

d. Approximate Diffusion Rate

1.	Helium out	100 cubic feet per 24 hours
2.	Air in	25 cubic feet per 24 hours

e. Blower size 6000 CFM at 11 inches H_2O

GENERAL

Life expectancy will be largely a function of exposure to the elements and careful handling procedures during installation. Resistance to abrasion and weatherability is very good for urethane coatings, consequently we would estimate the life expectancy of such a storage container to be approximately five years of continuous usage. Little or no maintenance would be required.

We know of no design standards for this type of helium storage. The closest related standards are probably those for "Air Houses" or "Air-supported Structures".

The limitations on this type of storage are primarily limitations in size due to material strength. The width (diameter) of the structure is limited to approximately 92 feet under the design conditions specified in your letter. There are no practical limits on the rate of fill since the system can be designed for nearly any desirable rate.

The cost of a storage system as described above having a storage capacity of 600,000 cubic feet is approximately $150,000.

Thank you for considering Viron as a possible source with respect to this requirement. If you have any further questions do not hesitate to contact us.

Sincerely,

VIRON DIVISION
Geophysics Corporation of America

John R. Breckenridge

John R. Breckenridge
Engineer

JRB/nw

Reeves Brothers
VULCAN DIVISION
1071 Avenue of ...
New York 18, N... PEnnsylvania 6-... · Teletype: New York 1-111

October 9th, 1964

Mr. D. L. McGinnis
Air Products & Chemicals, Incorporated
Allentown, Pennsylvania

Dear Mr. McGinnis:

Thank you for your letter of September 28th. Unfortunately, I cannot add anything further to our telephone conversation of October 7th. It appears that breather balloons would be unsatisfactory for your particular requirement due to the fact that the pressures involved are too great and the anticipated volume is far too large to make breather balloons practical. As stated, I feel that a vapor sphere or some other type of pressurized holder would be more satisfactory.

If our engineers can come up with any practical solutions, we will forward the information to you.

Sorry we could not be of further service.

Very truly yours,

REEVES BROTHERS, INC.
VULCAN DIVISION

E. R. Albert
E. R. Albert
Sales Manager

ERA:jts

cc: Mr. J. Hartwell

GENERAL AMERICAN TRANSPORTATION CORPORATION

380 Madison Avenue • New York 17, New York • OXford 7-2525

October 28, 1964

Air Products & Chemicals, Inc.
P. O. Box 538
Allentown, Pennsylvania

Att: Mr. D. L. McGuiness

Re: Helium Recovery
N.A.S.A. Project
Kennedy Space Center

Gentlemen:

The following will refer to our exploratory discussions recently to determine the essential criteria in the problem presented you by N.A.S.A. regarding recovery and purification of helium. In view of the fact that your current thinking is along the lines of a separate container at each launch position serviced by a mobile compressor transport, and since the location of your purification unit is not yet determined, we would offer the following commentary:

On consideration of a rigid structure, on which I understand no approval has yet been indicated, we would recommend your consideration of the Wiggins Gasholder, counter-balanced to afford the minimum collection back pressure. Except for the fact that adjacent sites are not closer than two miles and the launch sequence not known, it may still be possible to use one structure for two sites. This, of course, would require running light wall piping between with pressure sensitive boosters and with the containment structure located somewhere between the adjacent sites.

In order to facilitate your considerations I am attaching copies of our brochures entitled "The Wiggins Gasholder", "Wiggins Conservation Structures" and "Vapor Balancing Systems", with the latter being considerably out of date but included for your information. Separately attached, I have also noted specifics relative to the capacity ranges and operating pressures of three types of vapor containers, of which you will note that the only structure affording the capacities which you will require is the Wiggins Gasholder. I believe this sheet will supply most of the general information requested in your letter of September 28th, addressed to our Mr. J. C. Thompson.

GENERAL AMERICAN TRANSPORTATION CORPORATION

TO

Air Products & Chemicals, Inc.

While the polyethylene bag test which you described was successful, in the capacities involved here we would be much concerned about the possibility of wrinkle and aging failure, and the suitable manufacture and fabrication. While this, theoretically, would admirably meet the requirements, if your investigation should indicate that this is not feasible, then I think the rigid structure as indicated above should definitely be considered.

When the operating criteria are more clearly resolved, since General American is preeminent in the low pressure gas storage field in the United States, would further suggest your consideration of a design study contract with our corporation including possibly, an option to construct, on this project. With seven identical installations we feel that definite economies can be effected whether on the Wiggins Gasholder at the approximate figures indicated, or any other.

I have also included a general specification applied to a Wiggins Gasholder proposed for the City of New York which will serve to illuminate the data shown on our separately attached comparison and commentary sheet.

In accordance with our discussion, this data is transmitted for your consideration and upon completion of same we would be pleased to meet with you to explore this further.

Very truly yours,

GENERAL AMERICAN TRANSPORTATION CORPORATION

N. M. Wiseman

N. M. Wiseman
Sales Engineer

NMW:lg

Enclosure

Form E 193 10M 6-61

GENERAL AMERICAN TRANSPORTATION CORPORATION

ENGINEERING DEPARTMENT CHICAGO

DATE

BY

SUBJECT

BUILDING ORDER NO.

REF DWG NO.

SKETCH NO.

	(A.)	(B)	(C)
Type Struct →	Vapor Bag G.H.	Dry Seal/GH (Vapor Bag.)	Wiggins GH
Cap Range	50–150,000 ft^3	50–150,000 ft^3	50–5,000,000 ft^3
Nom. O.P. (Counterbal)	3/4 oz. Yes	−5/4 " + 1/4" H_2O Yes	4–20" H_2O No
w/Counter Bal.	—	—	±2.0" H_2O

(C) Wiggins Gasholder – Counterbal – ±2.0" H_2O

Nom Cap's.	Size		Budget Cost, (Ea.)
1) 250,000	79'-8 3/4" φ × 76'-4 3/4" φ × 62'-6 1/2"	St. Sh.	\$200,000
2) 500,000	93'-0 3/8" φ × 88'-9 7/8" φ × 91'-5 1/4"	" "	320,000
3) 1,000,000	119'-7 1/2" φ × 114'-0" φ × 112'-2 1/2"	" "	5[illegible] 000

Shipping wts appr. – 1) 600,000# 2) 800,000# 3) 1,000,000#

Permeation Rates (approx) – 1) 940 ft^3/yr – Helium – Based Min 1/3 full ANN. Indep. thruputs.

Notes – 12 yr Seal life. (Min Maint.)

Design – AISC + AWS.

Max. Pract. Rate fill – Piston Vel. 3–4'/min.

GENERAL AMERICAN TRANSPORTATION CORPORATION

PROPOSAL NO.: 42886

TO: CITY OF NEW YORK

WIGGINS GASHOLDER SPECIFICATIONS

Capacity 300,000 cu. ft.	Shell Inside Dia. 79'-8-3/4" x 76'-4-3/4"
Working Pressure (Inches of Water) 4"	Shell Height 74'-8-1/4"
	Shipping Weight 527130# (Est.)
Gas to be Stored -	Installed Weight 559,130# (Est.)

I. GENERAL DESCRIPTION:

The principle of operation of the WIGGINS GASHOLDER is primarily a piston in a cylinder with a gastight seal that allows the piston to move in the cylinder without friction or contact. For medium and large capacity gasholders, the piston is supplemented by a structural framework called a telescoping fender that moves vertically in the annular space between the piston and shell and serves to keep the gasholder shell to a minimum and economical height. The gas is contained in the space provided by the bottom, lower portion of the shell, inner and outer seals, and piston. The variation of the gas space is obtained by the vertical movement of the piston and telescoping fender. The operation of the gasholder is such that only the piston moves for the first 1/3 of the gasholder capacity. For the remaining 2/3 of the gasholder capacity the telescoping fender and piston move vertically as one unit. The guiding of the piston in the gasholder shell is accomplished by the seals and the balancing system. The seals maintain the piston and telescoping fender centered in the shell and prevent the rotation of these two structures. The balancing system, to be described later, maintains these structures in a level position. To protect the gasholder from overfilling, a volume control valve is furnished which is mechanically operated by the piston. The specified operating pressure when greater than the piston steel weight (approximately 2.5") is obtained by placing concrete weights on the piston.

II. MATERIALS:

All structural shapes and bars will conform to the most recent ASTM specifications A-7, standard specifications for steel in bridges and buildings. All plates shall conform to the most recent ASTM specifications A-283, Grade C, standard specifications for low and intermediate tensile strength carbon steel plates of structural quality. All sheets will be of commercial quality.

III. STRESSES:

The gasholder shall be designed to safely withstand all stresses to which it may be subjected within permissible deflection. The design shall conform with the following building codes:

American Institute of Steel Construction....1948
American Welding Society Standard
Rules for Field Welding of Steel
Storage Tanks..............................1947

The summary of the design stresses for A-7 steel as specified in the above codes are as follows:

Tension -------------------------- 20,000 lb. per sq.in.

Compression ----17,000 - 0.485 $(l/r)^2$
maximum l/r 120 for main members
maximum l/r 200 for secondary members

Bending -------------------------- 20,000 lb. per sq.in.

Shear ---- in net section of welds- 13,600 lb. per sq.in.

Shearing stress webs of beams ----- 13,000 lb. per sq.in.
Shearing stress bolts ------------- 10,000 lb. per sq.in.

Bearing stress milled surfaces ---- 30,000 lb. per sq.in.
Bearing stress fitted stiffeners -- 27,000 lb. per sq.in.

GENERAL AMERICAN TRANSPORTATION CORPORATION

PROPOSAL NO.: 42886

TO: CITY OF NEW YORK

IV. FOUNDATION:

Unless otherwise specified, the foundation will be furnished by others. Design loadings for the foundation will be furnished on request. In general, where the proposed erection site has a soil bearing capacity of $2000\#/ft^2$, a ring wall foundation under the shell and a sand pad over the grade will be sufficient. For preliminary estimates of the foundation, the installed weight of the gasholder given on page 1 can be used.

V. BOTTOM:

The bottom shall consist of 3/16" plates lap welded with a 1-1/4" lap, laid directly on a sand cushion or foundation as furnished by others.

VI. SHELL:

The shell shall consist of two cylinders with an offset which is known as Type B construction. The elevation of this offset is approximately 11'-0". The lower shell has an inside diameter of 74'-8-1/4", and the upper shell has an inside diameter of 76'-4-3/4". The shell consists (10 gauge) of ~~3/16"~~ plate, and the vertical and horizontal seams are ~~butt~~ LAP welded. Gastight construction is required for approximately the lower 45% of the shell. The shell above the outer seal connection serves as an abutment surface and weather housing only. The shell is designed for 30 lbs. per sq.ft. dynamic wind load pressure with a 0.7 coefficient of drag factor on a cylindrical shell and is stiffened by vertical and circumferential stiffeners where necessary. The vertical loads on the shell at the offset are carried to the foundation through structural supports.

VII. ROOF AND ROOF FRAMING:

The roof is a cone with a pitch of 3/4: in 12" and is supported by radial trusses, rafters and transverse beams. It is designed for a 25 lb. per sq.ft. snow or live load. The roof consists of 3/16" plates and lap welded construction with a 1" lap. The roof trusses and other supporting framework are of welded and bolted construction.

VIII. PISTON:

The piston consists of a flat bottom, structural reinforcement and a vertical fender at its periphery. The bottom consists of 3/16" steel plate and lap welded construction with a 1" lap. The structural reinforcement consists of radial members and cross bracing. These members are designed to withstand the full load of the piston and concrete weights when the piston is supported on pipe supports which is the maximum load condition. The piston fender consists of a framework of structural members and an abutment surface of #14 gage spiral sheets bolted and/or welded to this framework. The fender abutment surface is designed to control seal distribution and to withstand the compressive loads imposed on it by the gas pressure acting through the seal.

Pipe support nozzles are provided in the piston to make access to the underside of the piston possible. The pipe support nozzles are so arranged that with the piston floating at an elevated position it is possible to install support legs in the nozzles. This permits landing the piston at an elevation of approximately 3' above the bottom. Pipe support legs, unless specifically specified, are not furnished with the gasholder. (NOTE: It is felt that fabrication of pipe support legs when they are needed to inspect the bottom of the gasholder and underside of the piston, will be more satisfactory because of the probable lapse of time between completion of erection and inspection.)

The concrete weights used to obtain the specified working pressure of the gasholder are placed directly on the piston bottom.

IX. TELESCOPING FENDER:

The telescoping fender consists of a bottom circular girder, a framework of structural members, and a top girder. An abutment surface for the outer and inner seals of #14 gage spiral sheets is bolted and/or welded to the framework. The telescoping fender is designed for the compressive loads imposed by the working pressure acting through the seals.

X. . SEALS:

There are two seals in the Type B gasholder -- an outer seal and an inner seal. The outer seal extends from the shell connection to the bottom gastight circular girder of the telescoping fender, and the inner seal extends from the telescoping fender to the piston. The seal material is composed of a synthetic rubber compound reinforced with fabric yarns that are not susceptible to rot, weathering, or chemical reaction. The seal has a temperature range of 180° to -40° F. The seals serve as the gastight closure between the piston telescoping fender and shell.

XI. LEVELING SYSTEM:

To maintain the piston and telescoping fender in a level position, the gasholder is equipped with a leveling system that consists of a weight that imposes an uplift at two diametrically opposite points on the piston. The leveling weight travels vertically in a guide frame on the outside of the gasholder shell and acts on the piston through Bethanized or equal cables that are supported by cable sheaves placed on the roof of the gasholder. The leveling system will balance an eccentric live load on the piston or telescoping fender equal to the weight of the leveling weight. To balance the piston and telescoping fender in all quadrants, two weights are used and placed at 90 degrees to each other. The piston is designed to be in balance, and no normal eccentric loads are present. The cable sheaves are equipped with bronze bushings and are supported by corrosion resistant shafts on a suitable structural steel frame. Provisions are made to adjust the lengths of the leveling weight cables and to permit alignment between the sheaves and piston. All parts of the leveling system are external to the gas space and are readily accessible for inspection at all times.

XII. OPERATING OR WORKING PRESSURE:

The WIGGINS GASHOLDER shall be designed for the following operating pressures:

0 to 1/3 full.........2.73" inches water gage
1/3 full to full......4" inches water gage

XIII. ACCESSORIES:

A. The roof will be equipped with a suitable number of ventilator type 20" manways.

B. The shell will have access doors in the non-gastight portion located along the stairway or adjacent to the ladder, whichever is furnished, to provide access to the top side of the piston at all elevations.

C. The shell will have covered and screened ventilator openings in the non-gastight portion. The number will be consistent with the size of the gasholder and the vents will be symmetrically arranged vertically and circumferentially to give uniform ventilation.

D. The shell will be equipped with 1 20" shell manways located in the lower shell and 1 20" shell manway(s) in the upper shell above the offset.

E. The piston will be provided with 1 20" manway(s).

F. 3 condensate box(es) will be provided to drain the bottom. (The bottom of the WIGGINS GASHOLDER can be crowned slightly to provide good drainage).

G. An indicator board calibrated in units of volume will be furnished. This indicator is located adjacent to one of the leveling weights and the volume is indicated by a pointer attached to the leveling weight.

H. A volume control valve to protect the gasholder from overfilling will be furnished. The capacity of the valve will be ~~299,000~~ cu.ft. per hour based on a gas specific gravity of 1.0 and the maximum operating pressure of ______ inches water gage.

I. A pressure gage mounted on the shell will be provided to indicate the pressure of the stored gas.

J. The following nozzles will be provided: 1 - 18", ______. Unless otherwise specified, the length of the nozzle will be 6", it will be located in the lower shell, and it will be furnished with a full face flange. Nozzles smaller than 4" will be threaded.

ACCESSORIES: (Continued)

* K. Access to the roof will be provided by:

☐ An individual tread type steel spiral stairway welded directly to the shell.

☐ A straight caged ladder welded directly to the shell.

* X Zig-Zag stairs

XIV. WELDING:

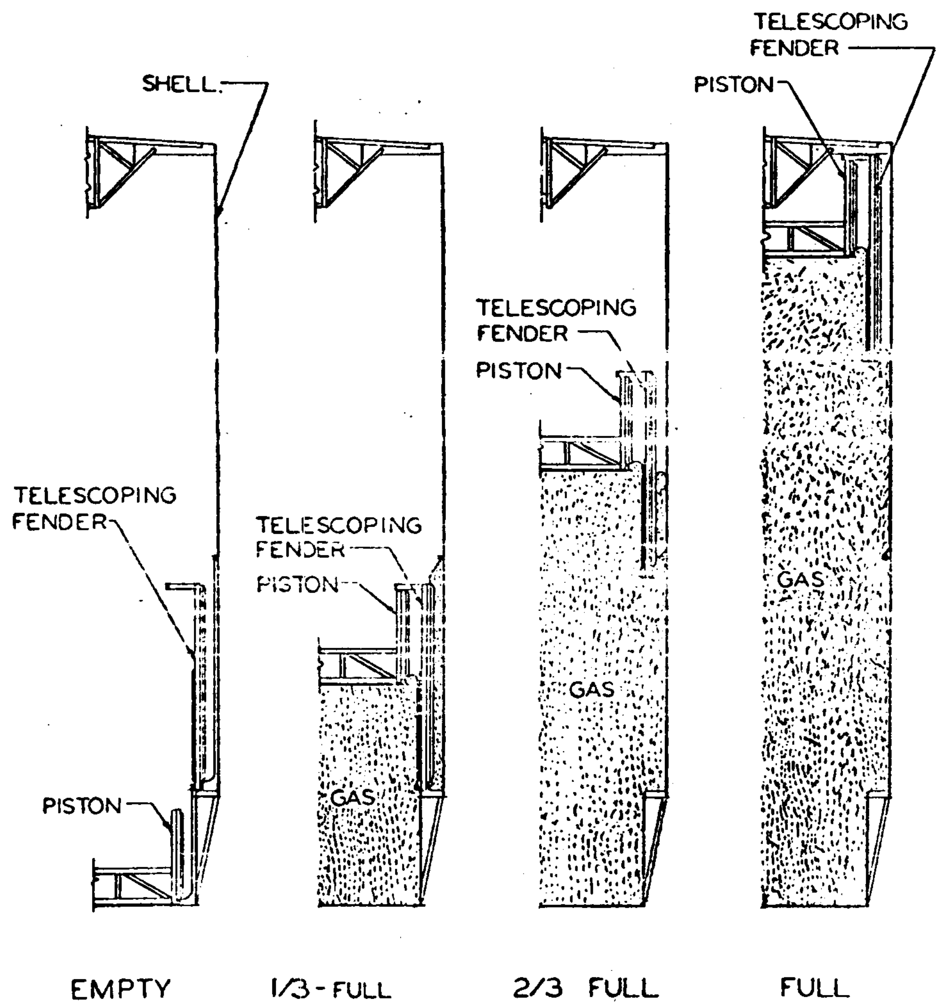
Welding on the gasholder shell will be in accordance with the American Welding Society Standard Rules for Field Welding of Steel Storage Tanks, 1947.

XV. TESTING:

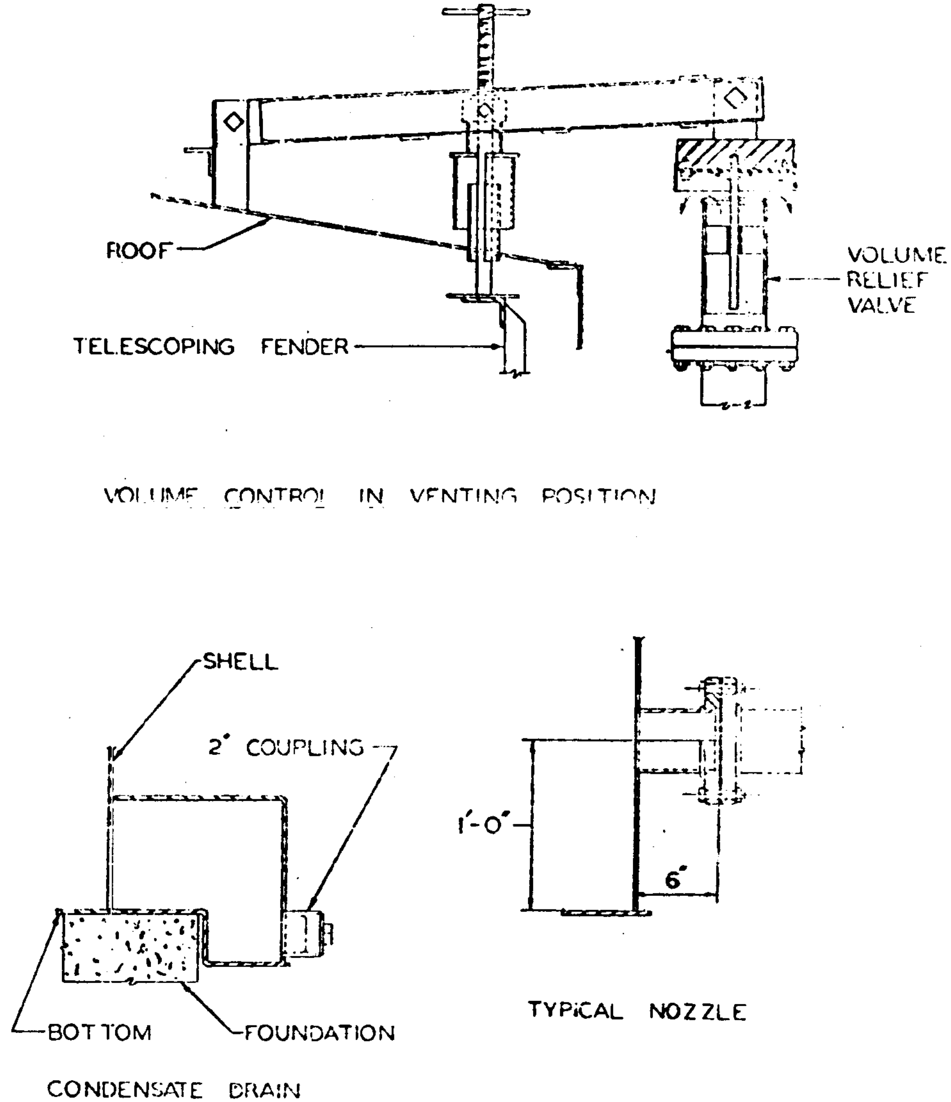
The welds in the bottom and piston bottom will be tested with a standard vacuum box and soap suds at a vacuum of not less than 5 lbs. The seal connections to the shell, telescoping fender and piston will be tested for gas tightness by soap suds or by flooding with water at the gasholder operating pressure after the gasholder has been completely erected. The remainder of the seams in the gastight portion of the gasholder will be tested at the specified working pressure by a standing leak test.

XVI. DRAWINGS:

For Approval:-
3 - copies of General Arrangement
After Approval:-
5 - copies of General Arrangement
Additional drawings or complete detail drawings will be furnished at extra cost.



OPERATIONAL DIAGRAM OF SEALS



SCHEMATIC OF TYPICAL FITTINGS

SPEC. SHEET WGB-8
5/1/53

Date: December 30, 1964

TRIP REPORT

of

D. J. Kelemen and D. L. McGinnis

Helium Recovery Study for MILA
NASA Contract Number NAS10-1472
APCI Project No. 00-4-1165

The purpose of this trip was the gathering of information concerning the flexible low pressure storage containers, used by NASA for the storage of low pressure helium, as fabricated by Birdair Structures, Inc. of Buffalo, N. Y.

The following summarizes the information obtained from personnel at NASA's Lewis Research Center, Cleveland, Ohio, December 29, 1964.

Tuesday - December 29, 1964 NAS10-1472

Persons Contacted: R. F. Hanlon, NASA
M. Scharer, NASA

After arriving at Lewis Research Center, our initial contact was with Mr. Scharer who briefly described the storage containers and their usage at Lewis and presented us with five black-and-white pictures of these containers. He then introduced Mr. Hanlon who had worked with these containers since their installation at Lewis. After hearing our requirements and stating that all of their problems were connected with contamination of stored pure helium by air permeating through the inner bag at the rate of 140 to 150 ppm per day, they advised that this type of storage should be compatible with our needs. The full report is outlined below.

The two storage containers used at Lewis Research Center are true hemispheres 92 feet in diameter and each capable of containing 200,000 scf of helium at a pressure of approximately one inch of water. Each container is composed of an inner hemisphere to contain the helium and an outer hemisphere to provide protection from the weather. The inner hemisphere material is hypalon-coated nylon fabric and as used at Lewis has a laminate of aluminized nylar on the helium or inner side. The outer hemisphere is made of neoprene coated nylon fabric, the outer surface of which is given a final coat of hypalon which acts both as a weathering agent and as a sunlight reflector. Blowers are used to inflate the outer shell with air. The air inside is vented through calibrated vents at the top to prevent accumulation of stagnant air inside, permitting work inside while the shell is inflated. The outer bag has a personnel hatch and two twelve inch windows to allow observation and actual inspection of the helium container while in use. The outer shells are designed for steady 75 MPH winds with gusts up to 85 MPH. However, the main enemy is not wind but the sun which deteriorates the nylon. This is the eventual cause of failure. The containers now at Lewis are one and four years old respectively, the four year old outer shell having had no maintenance during that time and due for replacement soon. With proper maintenance, painting the outer surface with hypalon every three years, the structure can be expected to have a service life of approximately ten years.

The persistent problem at Lewis with these containers is the permeation of air from the outer shell at 1 to 1-1/2 inches of water into the helium in the inner bag at approximately 0.1 inches of water less than the outer shell pressure. This permeation adds an average of 147 ppm per day of contaminants to the helium. Because of the helium being at a lower absolute pressure then the air in the outer shell, the loss of helium by permeation is minimized.

Contamination of the contained helium at the levels mentioned above would not affect ~~the use~~ of these containers for a helium recovery system at MILA. The added level of contamination would not be enough to cause resizing of the purification plant. Other factors such as available compressor sizes and performance ranges would affect plant size more.

Leakage would be less than that lost during gas transfers. During the development of the final design used at Lewis now, there were two failures of the outer shell. Both failures involved failure with hoop or circumferential seams. Adhesive was applied, the seams resealed and a precautionary band cemented over the seams. There have been no further failures of this kind.

During this failure, as during a blower failure, the outer shell collapsed slowly onto the inner container and remained there while the inner container was collapsed in withdrawing the helium. After all the helium was taken out and both bags lay on the base, repairmen walked out, fixed the defect as described above, and then started the blowers to return the outer shell to normal. The whole procedure can be finished in 5 or 6 hours after the bags have been deflated.

APPENDIX D

DELAWARE VALLEY SALES OFFICE
P. O. BOX 162, CHERRY HILL, N. J.

December 18, 1964

Air Products & Chemicals Inc.
P.O. Box 538
Allentown, Pa.

Attention: Mr. Dan Kelleman

Subject: SE 004-1165

Dear Mr. Kelleman:

Confirming recent conversation with our Mr. L. Kratz, we are enclosing specification sheet and estimate on Corblin Compressors to meet your requirements.

Bulletin 4074A, along with general cross section drawing, volumetric efficiency curve and dimension prints for units offered are enclosed.

The writer will contact you shortly regarding your requirements and further discussion.

Sincerely yours,

AMERICAN INSTRUMENT CO., INC.

John W. Crump

JWC/vcl/md
Encls.

American Instrument Co., Inc.
Silver Spring, Maryland

December 9, 1964
lak:gg

AIR PRODUCTS AND CHEMICALS
Allentown, Pennsylvania

Ref. SE004-1165

Item No.	1	2	3	4	5	6	6 Alternate	7
Model	nothing to offer	A5	A34	A5	A34	A2	A34	A5L
Suction pressure, psia	Capacity	180	180	14.7	180	180	180	14.7
Suction temperature, °F.	required	60	60	90	60	60	60	90
Discharge pressure, psia	too large.	220	220	225	220	220	220	225
Capacity, pounds/Mol/hr.	Three (3)	67	26.4	4.7	24.2	11.3	12.9	9.4
Speed - rpm	A5L machines	300	400	400	350	400	200	400
BHP	per Item 7	30	15	12	8	6	6.5	26
Motor included	would be needed.	40 hp, 1200 rpm	20 HP 1800 rpm	20 HP 1800 rpm	15 HP 1800 rpm	7-1/2 HP 1800 rpm	10 HP 1200 rpm	30 HP, 1800 rpm
Approx. skid dimensions and weight		8x4x5-1/2 7500#	5-1/2x3x5 3000#	8x4x5-1/2 7500#	5-1/2x3x5 3000#	4-1/2x3x4 2200#	5-1/2x3x5 3000#	8x4x5-1/2 10,000#
Cooling water required		1/4 gal/min/HP based on 20° rise and all HP going to heat						
Delivery - months		5	3	5	3	3	3	5
*Price each, FOB SS Md.		$13,979.00	$6781.00	$13,979.00	$6781.00	$4431.00	$6781.00	$21,347.00

*Price includes:

Compressor in low alloy steel construction with aftercooler, inlet and discharge pressure gage, discharge relief valve, motor in open dripproof inclosure, Multi-V-Drive, belt guard, interconnecting gas and water piping, all mounted and piped on a structural steel skid.

COMPRESSOR QUOTATION FROM FULLER COMPANY

DIVISION OF GENERAL AMERICAN TRANSPORTATION

I. Sutorbile Lube-Type

	I	Recip. 4	6
Cost W/O Motor	$15,000	$3,600	$6,500
Motor	500 HP	5 HP	200 HP
	600 RPM	1800	1200
	Induction	V Belt	Induction
BHP	495	2.5	168
H_2O	-	1 gpm	-
Aftercooler	270°	215°	300°
Weight	12000#	1700#	2500#
Dimension	11'L x 4'W x 6'H	7'L x 2'W x 3'H	8'L x 2'5"W x 3'H

COMPRESSOR QUOTATION FROM ROOTS-CONNERSVILLE

1. 45.5 scfm Unit - not able to handle @ 8 psig due to high temp. rise

   - prob 4-5 psig or higher cfm -

2. 8300 cfm @ 6 psig Unit

		Bhp	Motor
1854 RGS	580 rpm Dir. Conn.	365	400 hp
1841 RGS	700 rpm Dir. Conn.	335	350 hp
		(Not Synchronous)	

Temp. Rise	Costs W/O Motor	Include
143°F	\$15,200	Silencer, Guard, Exp. Joints
131°F	\$14,600	& Mounting Motor

Approximate Weight - 14,000# W/O Motor

Direct-Connected - Add Motor Dimension to L

L = 99" + Motor

W = 43" 24" ∅ inlet, 18" ∅ outlet, allow piping space

H = 60" silencers, use some reason HT = 10'

Silencer

Inlet = 129"

Outlet = 129" + extra (no info available)

3. 5200 cfm @ 6 psig

1442 RCS

795 RPM

V Belt Drive

235 Bhp

140°F Temp. Rise

$11,300 W/O Motor

11,000 lbs. weight

Dimensions

Motor + Blower side + side

L = 86" parallel to L is V Belt + Motor

W = 35" *Add Motor

H = 47" (Silencers included in height)

*W = Motor + V Belt Drive

Line Sizes

20" ∅ inlet

18" ∅ discharge

Blower and Motor vertical

with

Intercooler and Silencer = 112" Height

Quotation obtained from John Kash by telephone.

APPENDIX E

VEHICLE LAUNCH SITE INFORMATION

MATERIAL INDEX

January 11, 1965

NASA MERRIT ISLAND LAUNCH AREA

Drawing No.	Size	Sheet	Title	Prints	Repro.	Ref. No.
TAB No. F	E		MIC-C4 - Master Plan for Future Development	2		4-1165-001
TAB No. F	E		MIC-D4 - Master Plan for Future Development	2		4-1165-002
TAB No. F	E		MIC-C5 - Master Plan for Future Development	2		4-1165-003
FD-10230	E					
TAB No. 63	E		General Site Plan MIC-E-3 Future Development		X	4-1165-004
FD-10229	E		General Site Plan MIC-E-2 Future Development		X	4-1165-005
FD-10235	E		General Site Plan MIC-F1-PAD B Future Development	1	X	4-1165-006
FD-10236	E		General Site Plan MIC-F-2 PAD C Future Development		X	4-1165-007
75M05753	E	3 of 48	Complex 39-PAD "A" LH_2 Mechanical Key Plan	1		4-1165-008
75M05753	E	4 of 48	Complex 39-PAD "A" LH_2 Mechanical Storage Area Plan	1		4-1165-009
75M05753	E	48 of 48	Complex 39-PAD "A" LH_2 Mechanical Tower Pneumatics Req. Dia.	1		4-1165-010
			High Pressure Gas Systems			
75M-05870	E	5	Complex 39 Pneumatic Systems Mechanical Overall Site Plan	1		4-1165-011
75M-05870	E	6	Complex 39 Pneumatic Systems Mechanical Systems Schematic	1		4-1165-012
75M-05870	E	10	Complex 39 Pneumatic Systems Mechanical Helium Schematic	1		4-1165-013
75M-05870	E	31	Complex 39 Pneumatic Systems Mechanical Conv. Comp. Facility Gas, Helium Area Assembly	1		4-1165-014
75M-05870	E	52	Complex 39 Pneumatic Systems Mechanical Cross Country Piping Plan View	1		4-1165-015
75M-05870	E	74	Complex 39 Pneumatic Systems Mechanical PAD H.P. Storage Battery Schematic	1		4-1165-016
75M05870	E	75	Complex 39 Pneumatic Systems Mech. PAD. H.P. Storage Battery Plan View	1		4-1165-017
75M05870	E	89	Complex 39 Pneumatic Systems Mech. VAB. H.P. Storage Battery Schematic	1		4-1165-018
75M05870	E	90	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-019
75M05870	E	91	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-020
75M05870	E	92	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-021
75M05870	E	93	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-022
75M05870	E	94	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-023

NASA MERRITT ISLAND LAUNCH AREA
(Cont.)

Drawing No.	Size	Sheet	Title	Prints	Repro.	Ref. No.
75M05870	E	95	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-024
75M05870	E	96	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-025
75M05870	E	97	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-026
75M05870	E	100	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-027
75M05870	E	105	Complex 39 Pneumatic Systems Mech. VAB. High Press. Storage Battery Piping	1		4-1165-028
NASA 64-LO-F-236	D	1 of 7	NASA Launch Area Site Plan Ordinance Storage Facility		X	4-1165-029
64-LO-F-237	E		MLC-E-3 Complex 39 Master Plan	1	X	4-1165-030
63-LOC-9783	J		Complex 39 "A," "B," "C"		X	4-1165-031
203-102	E	2004	Complex 39 PAD "A" Pad Support Area General Plan-Grading and Site	1	X	4-1165-032
63-LOC-9885	D	1 of 3	LC-39 Arming Tower Park Position Area Plan	1	X	4-1165-033
60-08-243	E	202	Air Force Missile Test Center Complex 37 Master Site Plan	1		4-1165-034
VAB	E		Sketch of Vehicle Assembly Building	1		4-1165-035
036	A		Viron Circular for Expandables and Inflatables	3		4-1165-036
037	A		Launching Tower Sketch	1		4-1165-037
038	A		Merritt Island Launch Area Aerial Photo	1		4-1165-038
039	B		H.P. Helium Distr. System	Sheets3		4-1165-039

	Copies	Reference No.
Saturn V Ground Support Equipment Presentation Notes compiled by D. C. Crambilt G. Adcock	1	00-4-1165-040
SA-6 RP-1 Fuel System (Dwg. No. 10M30021) Functional description, index of finding numbers, and mechanical schematic	1	00-4-1165-041
SA-6 LH_2 System (Dwg. No. 10M30023) Functional description, index of finding numbers, and mechanical schematic	1	00-4-1165-042
Analytical Report NASA Launch Operations Center Merritt Island Launch Area Master Plan	1	00-4-1165-043
Launch Complex 39 Illustrations of various tower levels launcher rooms, and ground-to-LUT interface connections	1	00-4-1165-044
Saturn V Launch Support Equipment (SP-4-37D) General criteria and description by K-DF technical staff	1	00-4-1165-045
Saturn IB Vehicle (S-1B Stage) Fluid requirements (Dwg. No. 13M20097)	11	00-4-1165-046
Saturn (10M04157) V Vehicle (LOR Mission) to Ground Support Equipment information drawing	3	00-4-1165-047
20M97000 - Schematic Propulsion Control System S-IC	3	00-4-1165-048
- Schematic Propulsion Control System S-II	3	00-4-1165-049
LC-39 Ground Systems Schematics Rev. 1 & 2 Jan. 31, 1964	1	00-4-1165-050
Merritt Island Launch Area Master Plan	1	00-4-1165-051

	Copies	Reference No.
Office of Manned Space Flight Technical memorandum X-882, Apollo Systems Descriptions Vol. III	1	00-4-1165-052
Long Range Helium Transportation Optimization Study for NASA, KSC, MILA	1	00-4-1165-053
First Review of Findings Presentation on "Long Range Helium Transportation Optimization Study" for NASA Bureau of Mines	1	00-4-1165-054
Launch Area Helium Reclamation Study by Pan American Airways	1	00-4-1165-055
Viron - Capture Bags - Helium Recovery Study (File No. 17)	1	00-4-1165-056
Specialized Cost Study Launch Complex 39 Pneumatic System TR-4-13-2-D	1	00-4-1165-057
X. SA-6 Separation and Destruct Systems Functional Description, Index of Finding Numbers, and Mechanical Schematic (Dwg. No. 10M30030) File #6	1	00-4-1165-058
VI. SA-6 Environmental control system functional description, index of finding numbers, and mechanical schematics (Dwg. No. 10M30026) File No. 3 Helium Recovery Study	1	00-4-1165-059
VII. SA-6 Launch Pad accessories, functional description, index of finding numbers and mechanical schematics (Dwg. No. 10M30027) File #4 Helium Recovery Study	1	00-4-1165-060
IX. SA-6 RL10A-3 Engine and hydraulic system functional description, index of finding numbers and mechanical schematics (Dwg. No. 10M30029) File #5 Helium Recovery Study	1	00-4-1165-061

	Copies	Reference No.
V. SA-6 Pneumatic distribution system functional description, index of finding numbers and mechanical schematics (Dwg. No. 10M30025) File #2 Helium Recovery Study	1	00-4-1165-062
IV. SA-6 Nitrogen & Helium storage facility functional description, index finding numbers, and mechanical schematic (Dwg. No. 10M30024) Helium Recovery Study	1	00-4-1165-063
Introduction to Launch Support Equipment Engineering Division	1	00-4-1165-064
Equipment Engineering Division LO-P	1	00-4-1165-065
SA-7 Vehicle and Launch Complex Functional description, launch pad accessories - Chrysler Corporation	1	00-4-1165-066
Saturn V Vehicle (S-1C Stage) Fluid requirements (Dwg. 13M50096)	3	00-4-1165-067
Saturn V Vehicle Instrument Unit Fluid requirements (Dwg. 13M50099)	3	00-4-1165-068
Saturn V Vehicle (S-11 Stage) Fluids requirements (Dwg. 13M50097)	3	00-4-1165-069
Saturn V Vehicle (S-1VB Stage) Fluids requirements (Dwg. 13M50098)	3	00-4-1165-070
SK11-0058 (Umbilical Requirements AFT S-1C) Plate #34 Saturn V	3	00-4-1165-071
SK11-0059 (Umbilical Requirements AFT S-1C) Plate #12 Saturn V	3	00-4-1165-072
Saturn 1B Vehicle Loading Sequence Dwg. 10M30150	2	00-4-1165-073

	Copies	Repro.	Reference No.
Saturn 1B Vehicle Instrument Unit Fluids Requirements (13M20099)	2		00-4-1165-074
Saturn 1B Vehicle (S-1B Stage) Fluids Requirements (Dwg. 13M20097)	2		00-4-1165-075
Saturn 1B Vehicle (S-1VB Stage) Fluids Requirements (Dwg. 13M20098)	2		00-4-1165-076
Colored Photographs of Complex 34, 37 & 39 Saturn 1B Modified Pads A & B	6		00-4-1165-077
SK11-0067 Umbilical Requirements AFT S-1C Plate #32 Saturn V	3		00-4-1165-078
SK11-0060 Umbilical Requirements S-1C Intertank Saturn V	3		00-4-1165-079
SK11-0057 Umbilical Requirements Forward S-1C Saturn V	3		00-4-1165-080
SK11-0062 Umbilical Requirements S-11 AFT Saturn V	3		00-4-1165-081
SK11-0061 Umbilical Requirements Forward S-11 Saturn V	3		00-4-1165-082
SK11-0064 Umbilical Requirements AFT S-1VB	3		00-4-1165-083
SK11-0065 Umbilical Requirements S-1VB Forward Saturn V	3		00-4-1165-084
SK11-0066 Umbilical Requirements Instrument Unit Saturn V	3		00-4-1165-085
LC-39 VAB Area Plan Sheet 2 of 10	1	X	00-4-1165-086
Complex 39 Quantity Distance Site Plan	1	X	00-4-1165-087

Drawing No.	Size	Sheet	Title	Prints	Repro.	Ref. No.
10M30520	J	1 of 1	Saturn V Electro-mechanical Systems Bre-Launch Sequence of Operations	1		4-1165-088
No. 203-102	E	1090	Vicinity Plan (Complex 39)	1		4-1165-089
090			Minutes of Bropellants and Gases Meeting Subpanel of Saturn/Apollo Operations Panel Reports and Requirements	1 set		4-1165-090
091-203-100		9-09	LC 39 Vertical Assembly Building - Site Work Layout Plan 5	1 set		4-1165-091
092-203-100		9-03	LC 39 Vertical Assembly Building - Site Work - General Area Plan			4-1165-092
093-203-100		19-49	LC 39 Vertical Assembly Building - High Bay Area Nitrogen and Helium Flow Diagrams			4-1165-093
094-203-100		20-34	LC 39 Vertical Assembly Building - Low Bay Area Nitrogen and Helium Flow Diagrams			4-1165-094
095-20M97012			Schematic Propulsion Control System, S-IVB, Saturn V			4-1165-095
096-20M97002			Description of Propulsion System, S-IC			4-1165-096
097-20M97001			Index of Finding Numbers for Schematic Propulsion Control System, S-IC			4-1165-097
098-20M97013			Index of Finding Numbers for Schematic Propulsion Control System, S-IVB			4-1165-098
099-20M97014			Description of Propulsion Control System, S-IVB			4-1165-099
100-10M03369	J	1 of 1	Saturn V Inboard Profile - Rev. L	1		4-1165-100
101	A		Relative Distances for MILA			4-1165-101
102-201-104	E		Complex 37 - Cape Support Facilities Key Location Plan			4-1165-102
103			Second Review of Findings on Long Range Helium Transportation Optimization Study for NASA			4-1165-103
104			Factors Relating to Reliability Achievement in Saturn Vehicle SA-5; Volumes 1 and 2, Final Report			4-1165-104

APPENDIX F

MISCELLANEOUS REFERENCES

1. NASA Memorandums received during the study.
2. Engineering and Cost Data from the following sources:

Published Commercially Available References.

a. Manual of Industrial Construction, Estimating and Engineering Standards
Richardson Engineering Services, Downey, California

b. Cost Engineering Notebook, Published by American Association of Cost Engineers

c. National Construction Estimator, 1960 Edition, Craftsman Book Co.

d. Engineering Data Book, Natural Gas Processors Suppliers Association, 1957.

3. Past experience of Air Products and Chemicals, Inc.

TABLE I
REVISION NO. 1 - DATED NOVEMBER 17, 1964

SUMMARY OF HELIUM USAGE
SATURN V - APOLLO VEHICLE

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (lb.)	Helium Recoverable (lb.)	Total Vol. (Ft.3)	Impurities	Remarks	Rev.
	S-IC									
1.	PRESSURE CHECK RP-1 FUEL TANK	PAD	14	AMB	300	150	29,500	50% N_2	Recover from RP-1 fill-drain line.	
2.	ULLAGE PRESSURE RP-1 FUEL TANK	PAD	14	AMB	35	0	56,300	94% N_2	Negligible amount of helium. Propellant load test.	
3.	ULLAGE PRESSURE RP-1 FUEL TANK	PAD			35	0			For flight.	
4.	BLANKET PRESSURE LOX TANK	VAB	5	AMB	0	0	0	-	Gaseous nitrogen will be used on all LOX tanks.	1
5.	PRESSURE CHECK LOX TANK	PAD	22	AMB	7,210	7,210	611,800	7.8% N_2	Recover from LOX fill-drain line.	1
6.	ULLAGE PRESSURE LOX TANK	PAD	22	-297	104	0	155,000	94% N_2	Negligible amount of helium propellant load test.	
7.	ULLAGE PRESSURE LOX TANK	PAD			104	0			For flight.	

TABLE I (Continued)

Item No.	Operation	Location	Press. (psig)	Temp. (^oF)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. ($Ft.^3$)	Impurities	Remarks	Rev.
8.	HELIUM BOTTLES MISC. TESTS	VAB	1,500	AMB	4,810	2,400	232,000	Pure		
9.	HELIUM BOTTLES MISC. TESTS	PAD	1,500	AMB	480	91	23,000	62% N_2		
10.	HELIUM BOTTLES	PAD	3,000	-295	646	440	62,000	32% N_2	Recover from RP-1 fill drain line, propellant load test.	
11.	HELIUM BOTTLES	PAD			646	0			For flight.	
11.1	TOTALS S-IC STAGE	VAB PAD FLIGHT			4,810 8,775 785 14,370	2,400 7,891 0 10,291	232,000 726,300 0 958,300			1
	S-II									
12.	BLANKET PRESSURE LH_2 FUEL TANK	VAB	5	AMB	5,960	5,960	613,400			
13.	VEHICLE CHECKS LH_2 FUEL TANK	VAB	8	AMB	3,980	2,000	193,000			
14.	P.U. PURGE LH_2 FUEL TANK	VAB	5	AMB	3,760	3,760	363,000	2.7% N_2 20 ppm O_2	Impurities average for the four operations shown.	
15.	PURGE LH_2 TANK PRIOR TO TRANSPORT	VAB	5	AMB	3,260	2,730	263,000			

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (^oF)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. ($Ft.^3$)	Impurities	Remarks	Rev.
16.	PRESSURE TEST LH_2 FUEL TANK	PAD	10	AMB	270	270	25,600	Pure		
17.	PURGE OF LH_2 FUEL TANK	PAD	-	-	0	0	0	-		1
18.	INERT LH_2 TANK AFTER LOX LOAD TEST	PAD	-	-	0	0	0	-	Inerting operation not required since loading of LOX and LH_2 performed on same day.	1
18.1	P.U. CALIBRATION PRIOR TO LAUNCH	PAD	5	AMB	3,760	3,760	363,000	Pure		
19.	ULLAGE PRESSURE LH_2 FUEL TANK	PAD	15	-423	210	210				
20.	DRAIN LH_2 FUEL TANK	PAD	15	-423	2,000	2,000	537,000	16.7% H_2	LH_2 Load Test.	
21.	INERT LH_2 TANK AFTER LH_2 LOAD TEST	PAD	5	-423	2,425	2,425				
22.	ULLAGE PRESSURE LH_2 FUEL TANK	PAD			210	0			For flight.	
23.	BLANKET PRESSURE LOX TANK	VAB	5	AMB	0	0	0		Gaseous nitrogen will be used on all LOX tanks.	1

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.^{3})	Impurities	Remarks	Rev.
24.	VEHICLE CHECKS LOX TANK	VAB	11	AMB	1,960	980	94,500	5.0 N_2 155 ppm O_2	Impurities average for the four operations shown.	
25.	P.U. PURGE LOX TANK	VAB	5	AMB	1,585	1,585	153,000			
26.	PURGE LOX TANK PRIOR TO TRANSPORT	VAB	5	AMB	0	0	0		Operation not required.	1
26.1	FULL PRESSURE TEST	PAD	22	AMB	1,817	1,817	188,480	9.2% N_2		1
26.2	P.U. PURGE LOX TANK	PAD	5	AMB	1,585	1,585	153,000	Pure		1
27.	ULLAGE PRESSURE LOX TANK	PAD	22	-297	81	81	61,520	88% N_2		1
28.	DRAIN LOX TANK	PAD	22	-297	0	0	0	-		1
29.	PURGE LOX TANK	PAD	5	-297	0	0	0			1
30.	ULLAGE PRESSURE LOX TANK	PAD			81	0			For flight.	
31.	HELIUM BOTTLES MISC. TESTS	VAB	1,500	AMB	711	350	34,000	Pure		
32.	HELIUM BOTTLES LOAD TESTS	PAD	3,000	-275	68	68	5,600	Pure	Recover at end of propellant load tests.	

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.³)	Impurities	Remarks	Rev.
33.	HELIUM BOTTLES ON ENGINES	PAD	3,000	AMB	18	0			Discharged through engines.	
34.	HELIUM BOTTLES	PAD			86	0			For flight.	
35.	THRUST CHAMBER PURGE AND COOL-DOWN	PAD	0	-250	700	0			Discharged through engines. Load test.	
36.	THRUST CHAMBER PURGE AND COOL-DOWN	PAD			700	0			For flight.	
37.	MISC. PURGE AND BUBBLING	PAD			160	0			Individual quantities small. Load test.	
38.	MISC. PURGE AND BUBBLING	PAD			160	0			For flight.	
39.	TOTALS S-II STAGE	VAB PAD FLIGHT			21,216 13,094 1,237 35,547	17,365 12,216 0 29,581	1,713,900 1,334,200 0 3,048,100			
	S-IVB									
40.	BLANKET PRESSURE LH_2 FUEL TANK	VAB	5	AMB	1,630	1,630	167,500			

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.^{3})	Impurities	Remarks	Rev.
41.	VEHICLE CHECKS LH_2 FUEL TANK	VAB	10	AMB	1,440	700	67,500			
42.	P.U. PURGE LH_2 FUEL TANK	VAB	5	AMB	1,200	1,200	116,000	2.4% N_2 25 ppm O2	Impurities average for the four operations shown. Incl. Item 40.	
43.	PURGE LH_2 TANK PRIOR TO TRANSPORT	VAB	5	AMB	990	845	81,500			
44.	PRESSURE TEST LH_2 FUEL TANK	PAD	20	AMB	145	145	13,960	Pure		1
45.	PURGE OF LH_2 FUEL TANK	PAD	5	AMB	0	0	0		Inerting operation not required since LOX and LH_2 loading performed on same day.	1
46.	INERT LH_2 TANK AFTER LOX LOAD TEST	PAD	5	-50	0	0	0			
47.	ULLAGE PRESSURE LH_2 FUEL TANK	PAD	20	-423	16.5	16.5	Inc. in Item 49		LH_2 load test.	
48.	DRAIN LH_2 FUEL TANK	PAD	22	-423	418	418	Inc. in Item 49		LH_2 load test.	
49.	INERT LH_2 TANK AFTER LH_2 LOAD TEST	PAD	5	-423	990	990	195,000	30% H_2	LH_2 load test.	

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. ($Ft.^3$)	Impurities	Remarks	Rev.
49.1	P.U. PURGE OF LH_2 TANK	PAD	5	AMB	1,200	1,200	116,000	Pure		1
50.	ULLAGE PRESSURE LH_2 FUEL TANK	PAD			16.5	0			For flight.	
51.	BLANKET PRESSURE LOX TANK	VAB	5	AMB	0	0	0		Gaseous nitrogen used.	1
52.	VEHICLE CHECKS LOX TANK	VAB	15	AMB	565	280	27,000	8.3% N_2 0.2% O_2	Impurities average for the two operations shown.	1
53.	P.U. PURGE LOX TANK	VAB	5	AMB	43	43	4,150			1
54.	PURGE LOX TANK PRIOR TO TRANSPORT	VAB	5	AMB	0	0	0		Operation not required.	1
54.1	FULL PRESSURE TEST LOX TANK	PAD	29	AMB	386	386	38,220	0.84% N_2		1
55.	ULLAGE PRESSURE LOX TANK	PAD	29	-297	8.5	8.5	820	Pure		1
56.	DRAIN LOX TANK	PAD	22	-297	0	0	0		Operation not required.	1
57.	PURGE LOX TANK	PAD	5	-297	0	0	0		Operation not required.	1

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (^{o}F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. ($Ft.^3$)	Impurities	Remarks	Rev.
57.1	P.U. PURGE LOX TANK	PAD	5	AMB	43	43	4,150	Pure		1
58.	ULLAGE PRESSURE LOX TANK	PAD			8.5	0			For flight.	
59.	HELIUM BOTTLES MISC. TESTS	VAB	1,000	AMB	1,877	935	90,200	Pure		1
60.	HELIUM BOTTLES FOR FULL PRESSURE TEST	PAD	1,000	AMB	32	32	3,100	Pure	Recover at end of LH_2 load test.	1
61.	HELIUM BOTTLES FOR LOX TANK	PAD	3,100	-410	397	397	38,300	Pure	Recover at end of LH_2 load test.	
62.	HELIUM BOTTLES	PAD			495	0			For flight.	
63.	THRUST CHAMBER PURGE AND COOL-DOWN	PAD	0	-410	140	0			Discharged through engines. Load test.	
64.	THRUST CHAMBER PURGE AND COOL-DOWN	PAD			140	0			For flight.	
65.	MISC. PURGES	PAD			17	0			One half flight, one half propellant load test.	

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.^{3})	Impurities	Remarks	Rev.
65.1	TOTALS S-IVB STAGE	VAB PAD FLIGHT			7,745 3,785 668 12,198	5,633 3,636 0 9,269	553,850 409,550 0 963,400			
	APOLLO									
66.	SER. MOD. PURGE	IND. A.	5	AMB	90	630	63,000	3.5% N_2 80 ppm O_2	Impurities are average for operations shown.	
67.	SER. MOD. PRESSURE TEST	IND. A.	300	AMB	130					
68.	PROPELLANT SYSTEM CHECKOUT	IND. A.	2,200 5,000	AMB	400					
69.	LEM ASCENT-DESCENT BOTTLES	IND. A.	3,500	-250	165					
70.	LEM ASCENT-DESCENT BOTTLES	PAD			55	0			For flight.	
71.	TOTALS APOLLO SPACE CRAFT	IND. A FLIGHT			785 55 840	630 0 630	63,000 0 63,000			

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.3)	Impurities	Remarks	Rev.
	COMPRESSOR-CONVERTER FACILITY									
72.	COMPRESSOR BLOWDOWN	CCF	6,000	AMB	1,500	1,500	145,000	Oil and Water	Assumed once per day for 58 days.	
73.	REGENERATE PURIFICATION SYSTEM	CCF	6,000	AMB	1,170	1,170	116,000	2.3% N_2 0.6% O_2	Based on preliminary size information and application to Complex 34 and 37 CCF only.	1
74.	TOTALS-CCF	(PAD 39) only			1,500	1,500	145,000			
	MOBILE LAUNCH STRUCTURE									
75.	BLOWDOWN PRIOR TO TRANSPORT	PAD	6,000	AMB	36	36	3,500	Pure		
	PAD AREA									
76.	INERTING LH_2 CROSS-COUNTRY FILL-DRAIN LINE	PAD	5	AMB*	5,000	4,000	422,200	7.2% H_2	Once after LH_2 load test, once before and after LH_2 load for flight.	1

* Initial purge temperature can be as low as -410°F.

TABLE I (Cont.)

Item No.	Operation	Location	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.^{3})	Impurities	Remarks	Rev.
77.						OVERALL SUMMARY				
		AREA		POUNDS		POUNDS		SCF*		
77.1		VAB		33,771		25,398		2,499,750		
77.2		PAD		30,690		27,779		2,895,750		
77.3		FLIGHT		2,745		0		0		
77.4		IND. A.		785		630		63,000		
77.5		CCF		1,500		1,500		145,000		
77.6		GRAND TOTAL		69,491		55,307		5,603,500		

* SCF is based on 70°F and 14.7 psia.

TABLE II

JANUARY 5, 1965 - REVISED FEBRUARY 9, 1965

SUMMARY OF HELIUM USAGE
SATURN IB VEHICLE

Item No.	Operation	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. ($Ft.^3$)	Impurities	Remarks	Rev.
	S-IB								
1.	PRESSURE CHECK RP-1 FUEL TANK	17.6	AMB	885	825	85,600	6.7% N_2	Recover from RP-1 fill-drain line.	
2.	ULLAGE PRESSURE RP-1 FUEL TANK	17.6	AMB	1	.54	6,700	99% N_2	Negligible amount of helium. Propellant load test.	
3.	ULLAGE PRESSURE RP-1 FUEL TANK			1	0			For flight.	
4.	PRESSURE CHECK LOX TANK	52.5	AMB	2,140	2,047	208,000	4.3% N_2	Recover from LOX fill drain line.	
5.	ULLAGE PRESSURE LOX TANK	52.5	-297	5	3.5	20,500	98% N_2	Negligible amount of helium. Propellant load test.	

TABLE II (Continued)

Item No.	Operation	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.^{3})	Impurities	Remarks	Rev.
6.	ULLAGE PRESSURE LOX TANK			5	0			For flight.	
7.	HELIUM BOTTLES MISC. TESTS	1500	AMB	714	357	34,400	Pure	Requires piping to overboard vent.	
8.	HELIUM BOTTLES LOAD TEST	3000	AMB	126	126	12,200	Pure	Requires piping to overboard vent.	1
9.	HELIUM BOTTLES PRESSURIZATION			126	0			For flight.	
10.	MISC.			22	0			LOX bubbling, etc.	
11.	S-IB TOTALS								
	GROUND			3,893	3,355	340,200			
	FLIGHT			132	0	0			
				4,025	3,355	340,200			
	S-IVB								
12.1	BLANKET PRESS. LH_2 FUEL TANK	5	AMB	1,120	1,120			Included in item 12.2.	
12.2	VEHICLE CHECKS LH_2 FUEL TANK	10	AMB	1,440	700	316,000	3.3% N_2 35 ppm O_2	Impurities average for the four operations shown.	1

TABLE II (Cont.)

Item No.	Operation	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. ($Ft.^3$)	Impurities	Remarks	Rev.
12.3	P.U. PURGE LH_2 FUEL TANK	5	AMB	1,200	1,200			Included in item 12.2.	
12.4	PRESSURE TEST LH_2 TANK	20	AMB	145	145			Included in Item 12.2.	1
13.1	ULLAGE PRESSURE LH_2 FUEL TANK	20	-423	16.5	16.5				
13.2	DRAIN LH_2 FUEL TANK	22	-423	418	418	195,000	30% H_2	Tanking test.	
13.3	INERT LH_2 TANK AFTER LH_2 LOAD TEST	5	-423	990	990				
14.	P.U. PURGE LH_2 FUEL TANK	5	AMB	1,200	1,200	116,000	Pure		
15.	ULLAGE PRESSURE LH_2 FUEL TANK			16.5	0			For flight.	
16.	VEHICLE CHECKS LOX TANK	15	AMB	565	280	31,150	8.3% N_2 .2% O_2		
17.	P.U. PURGE LOX TANK	5	AMB	43	43				
18.	PRESSURE TEST LOX TANK	29	AMB	386	386	38,220	.84% N_2		

TABLE II (Cont.)

Item No.	Operation	Press. (psig)	Temp. (°F)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. (Ft.^{3})	Impurities	Remarks	Rev.
19.	ULLAGE PRESSURE LOX TANK	29	-297	8.5	7	14,000	75% N_2 20% O_2	Negligible amount of helium. Propellant load test.	
20.	P.U. PURGE LOX TANK	5	AMB	520	500	50,000	5.7% N_2		
21.	ULLAGE PRESSURE LOX TANK			8.5	0			For flight.	
22.	HELIUM BOTTLES MISC. TESTS	1,000	AMB	1,880	940	90,200	Pure		
23.A	HELIUM BOTTLES PRESSURE TEST	1,000	AMB	32	32	41,400	Pure		1
23.B	HELIUM BOTTLES TANKING TEST	3,100	-410	397	397				1
24.	HELIUM BOTTLES			495	0			For flight.	
25.	THRUST CHAMBER PURGE AND COOL-DOWN			280	0			Tank test and flight.	
26.	MISC. PURGES			17	0			Flight.	

TABLE II (Cont.)

Item No.	Operation	Press. (psig)	Temp. (^oF)	Helium Used (Lb.)	Helium Recoverable (Lb.)	Total Vol. ($Ft.^3$)	Impurities	Remarks	Rev.
27.	S-IVB TOTALS								
	GROUND			10,361	8,367	877,970			1
	FLIGHT			817	0	0			1
				11,178	8,367	877,970			
28.	LH_2 FILL-DRAIN LINE PURGE	5	-410 AMB	800	800	86,000	6.5% H_2	Once before and after tanking test, once before and after load for flight.	
	OVERALL SUMMARY								
	GROUND			15,055	12,500	1,304,170			1
	FLIGHT			950	0	0			1
				16,005	12,500	1,304,170			

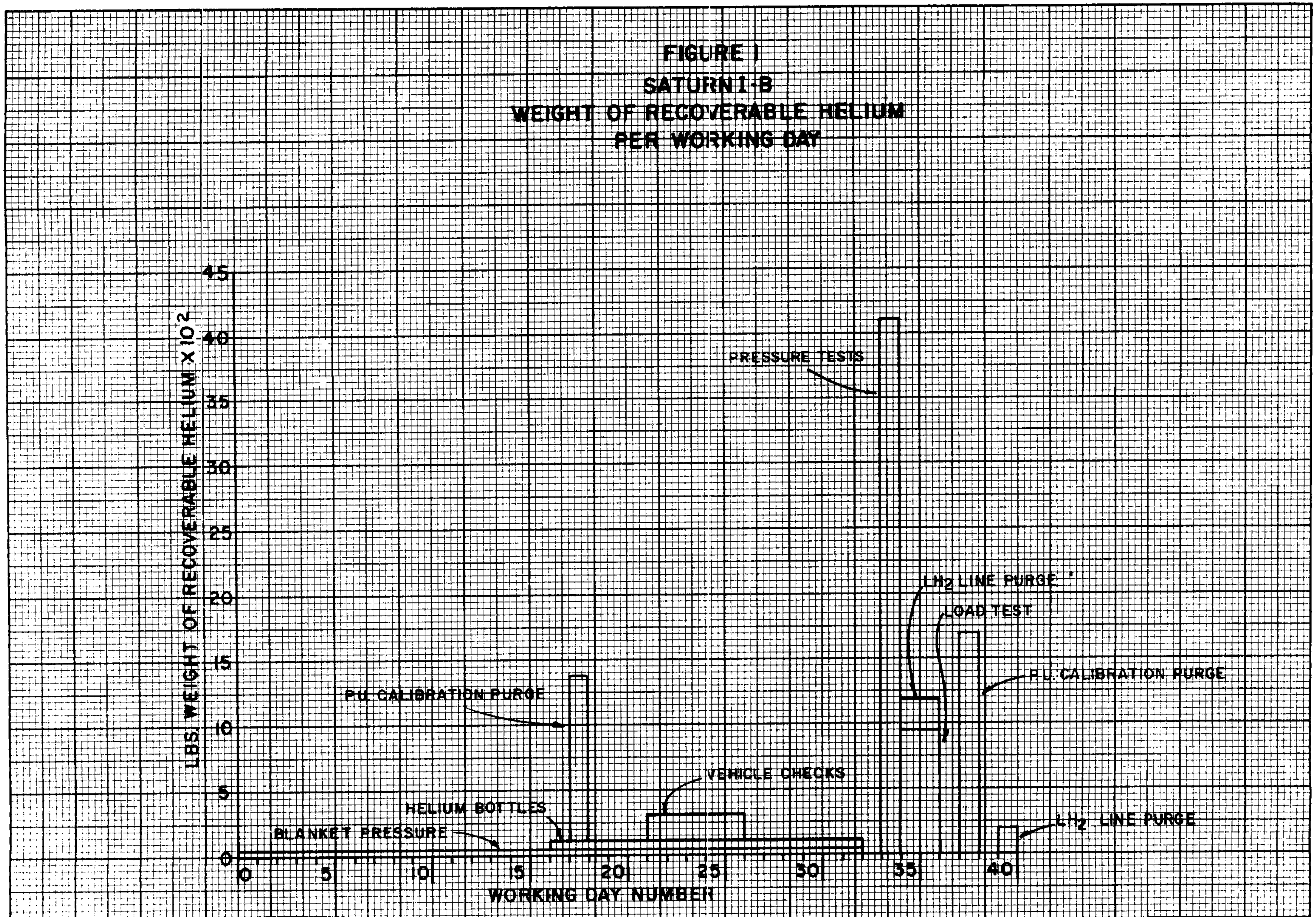


FIGURE I
SATURN I-B
WEIGHT OF RECOVERABLE HELIUM
PER WORKING DAY
LBS. WEIGHT OF RECOVERABLE HELIUM X 10²
0
5
10
15
20
25
30
35
40
45
WORKING DAY NUMBER
PRESSURE TESTS
LH2 LINE PURGE
LOAD TEST
P.U. CALIBRATION PURGE
VEHICLE CHECKS
HELIUM BOTTLES
BLANKET PRESSURE
LH2 LINE PURGE

FIGURE IA
SATURN I-B
VOLUME OF RECOVERABLE CONTAMINATED HELIUM PER WORKING DAY

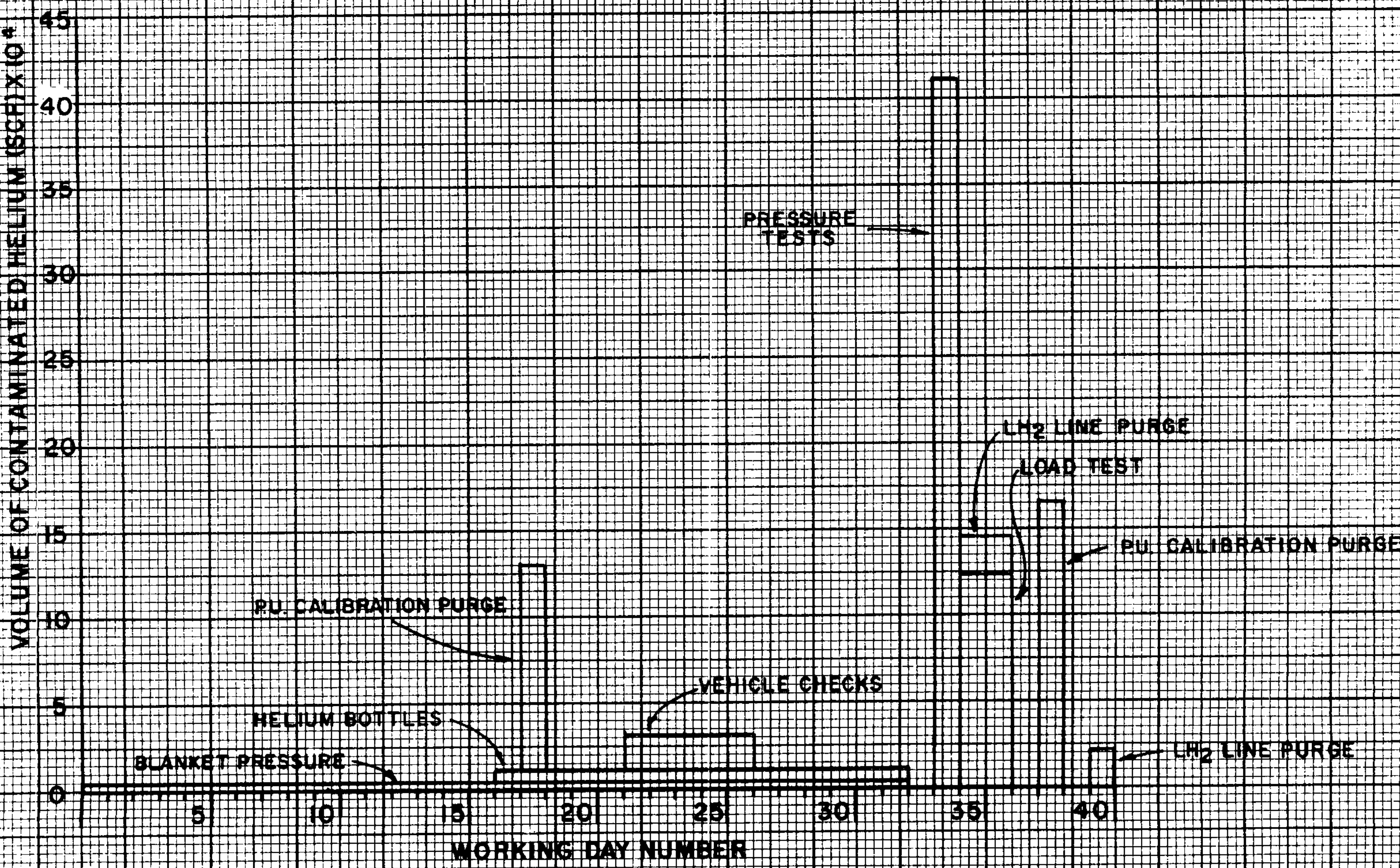


FIGURE 2

SATURN V

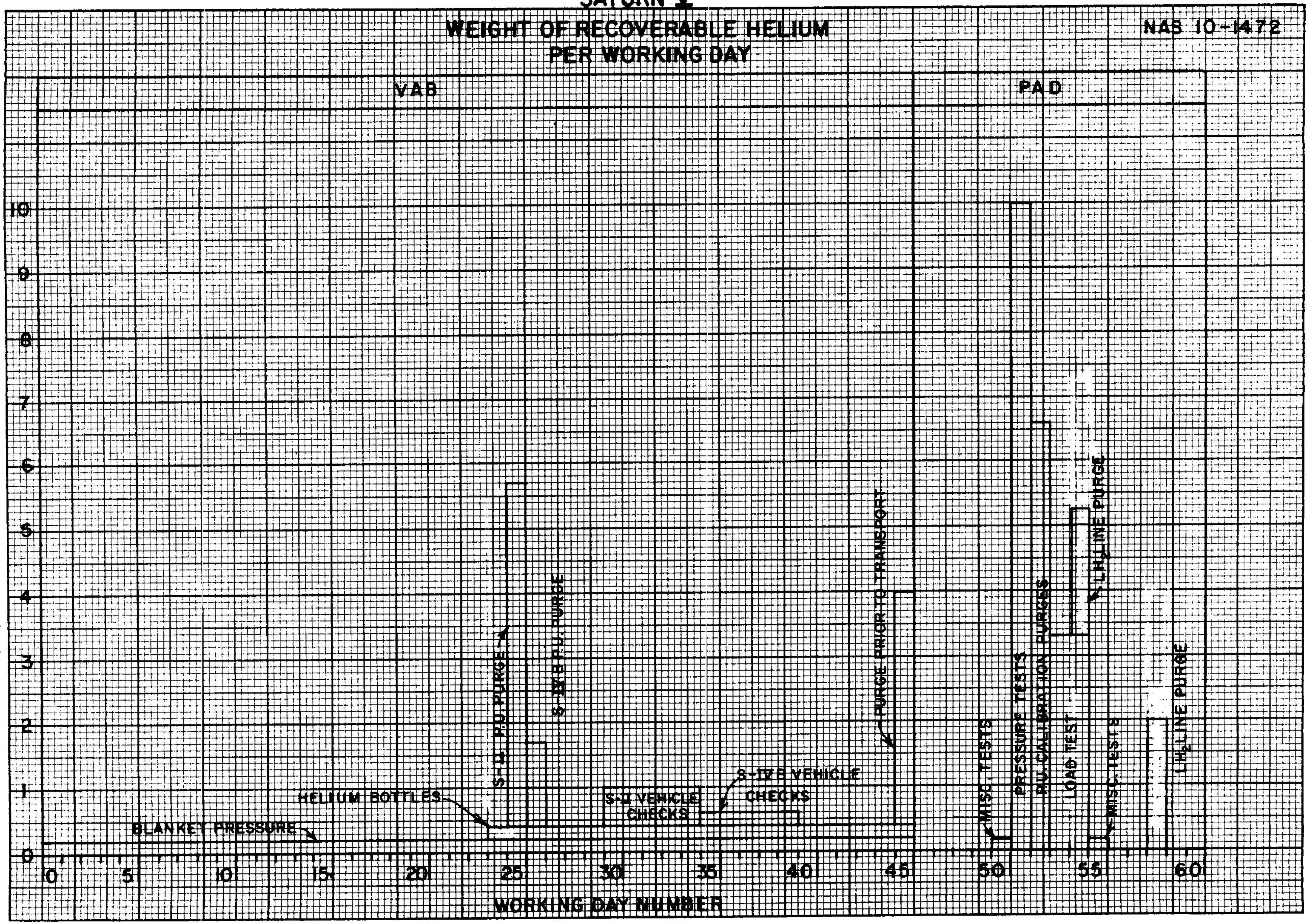


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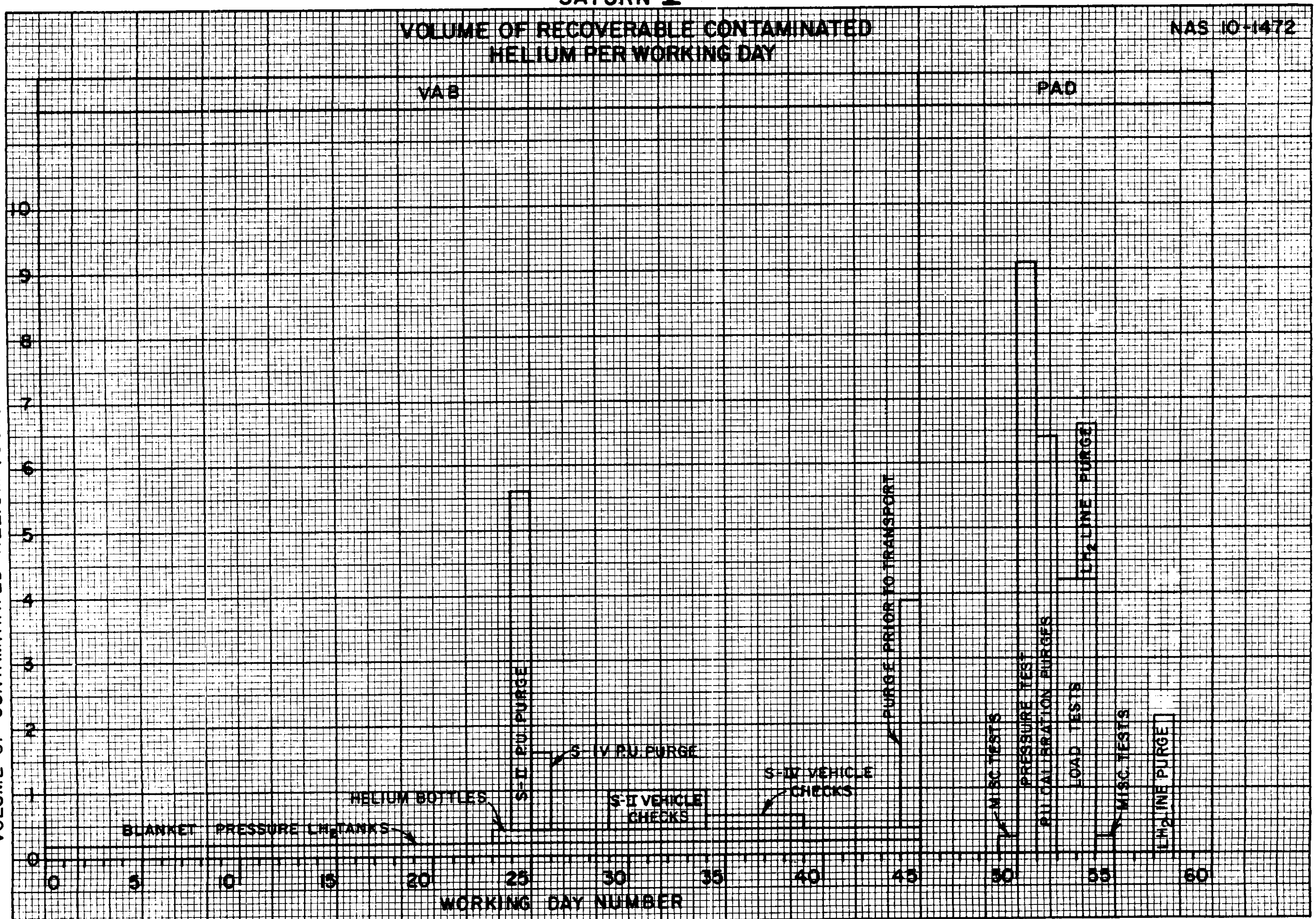
FIGURE 3
SATURN V



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