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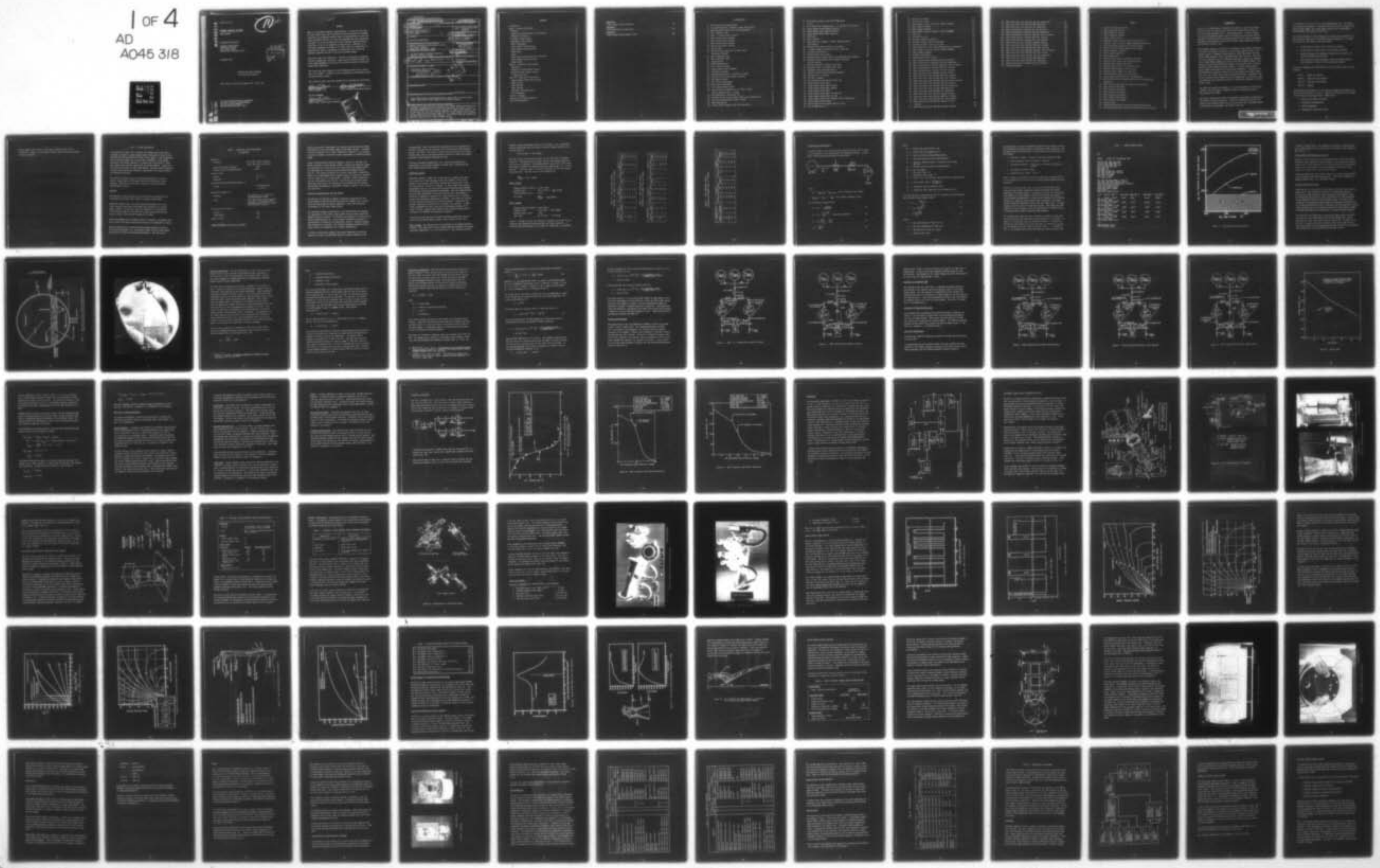

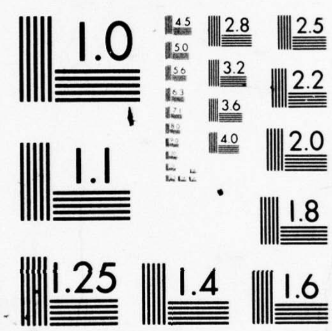

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TARGET ENGINE SYSTEM

FINAL REPORT

ENGINEERING DEPARTMENT

ROCKWELL INTERNATIONAL
ROCKETDYNE DIVISION
6633 CANOGA AVENUE
CANOGA PARK, CALIFORNIA 91304

September 1977

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Final Report for Period September 1975 - March 1977

AIR FORCE ROCKET PROPULSION LABORATORY
Director of Science and Technology
Air Force Systems Command
Edwards AFB, California 93523

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This report has been reviewed by the Information Office and is releasable to the (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
A program to design, fabricate, and test three Target Engine Systems was completed for the Air Force Rocket Propulsion Laboratory in support of the AF Geophysics Laboratory. The designs consisted of flight-proven hardware. The two versions (the low-thrust version employing an RS-14 engine and the high-thrust a modified Atlas vernier) made use of a common design, pressurization, and propellant feed system and structure. Construction utilized a mockup for reference purposes and to reduce program costs.

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INTRODUCTION

As part of the MSMP program, Rocketdyne was awarded a contract to design, fabricate, test, and deliver three small rocket stages that mounted on top of an Aries sounding rocket. These stages would be flown as targets for optical experiment stages, which were mounted atop the launch vehicle assembly and using specially developed sensors (IR, UV, spatial radiometer, photometer, spectrometer) would track the small rocket stage while obtaining scientific spectral data.

This document presents the results of a program for the design, fabrication, functional verification, delivery, of three target engine systems. Each system consists of pneumatic pressurization, propellant tanks, controls, rocket engine assembly, flight instrumentation, and structure. The structure has an interface that is compatible with sensor payload and remaining target engine module segments for use in both TEM and HPTEM flights. Two systems use the Rocketdyne RS-1401 engine, and one system uses a modified Rocketdyne Atlas Vernier LR101-NA-7 engine. All three target systems employ common pressurization and feed system components. Propellants are NTO and MMH with propellant expulsion from Rocketdyne Atlas engine (LR101-NA-7) fuel start tanks pressurized with gaseous nitrogen. Propellant feed control during attitude changes and control maneuvers is provided by internal baffles in each propellant tank and a cold-gas ACS attached to the TES during flight.

The propulsion system is packaged in a 37.5-inch-diameter by 59-inch-long envelope. The dry weight of either the high- or low-thrust system is approximately 485 pounds.

Each target engine system (TES) was assembled at Rocketdyne, inspected and certified for hot-fire operation. Cold-flow calibration tests were performed on the complete system in the hot-fire test area to minimize setups, instrumentation requirements, and overall flow time.

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On completion of the hot-fire functional verification test, the systems were prepared for shipment. Following launch and recovery at White Sands Missile Range (WSMR), each target engine system will be disassembled, decontaminated, and stored for future use.

The central objective of this program was to deliver three systems to be launched with a high level of confidence and at minimum cost. To reach this objective, four major actions were taken:

1. An experimental drawing release method was employed.
2. Use was made of flight proven, off-the-shelf components.
3. Quality Assurance and Inspection services were provided, primarily by Engineering personnel.
4. Use was made of excess government inventory hardware known to exist and able to adapt to this specific application.

This report describes the interrelations of the following tasks for this program:

Task I: Design and Analysis

Task II: Fabrication and Assembly

Task III: Functional Verification

Task IV: Shipment

Refurbishment plans (Task V) at this time are minimal and encompass only those activities that will lead to a rebuild at Rocketdyne after a launch. The following is anticipated after a WSMR launch:

1. Recovery and safing operations
2. Propellant decontamination
3. System disassembly
4. Packaging for long-term storage

Flight support effort (Task VI) has been initiated in the form of procedures to support the pre-launch checkout operations and post-flight recovery activities.

TASK I: DESIGN AND ANALYSIS

The objective of Task I was to perform the analysis and design effort necessary to develop a target engine system configuration, based on the specified RS-1401 and LR101-NA-7 Atlas vernier engines. The configuration was to utilize minimum-cost, off-the-shelf components, proved design approaches, and design commonality to ensure that the RS-1401 or LR101-NA-7 engines were directly usable with the system hardware. Design configurations were based on these requirements: specified engine operating; structural and electrical; prelaunch, operational, and recovery safety; and minimized servicing.

The analysis conducted in Task I included consideration of mission effects, range safety, GFP hardware (RS-1401 and LR101-NA-7 rocket engines), structural and electrical interfaces, and servicing and refurbishment criteria.

MISSIONS

The objective of this subtask was to define mission requirements and environments and assess their impacts on engine system design.

Preliminary mission duty cycle and operating environment for the in-flight operation and launch environment were defined for the target engine systems. Mission duty cycle was defined as the equivalent of five 5-second firings for the LR101-NA-7 engine and multiple RS-1401 firings, based on the LR101-NA-7 propellant loading.

Launch environment data, including effects of vibration, aerodynamic heating, g levels, and impact velocity and attitude, are summarized in Table 1.

Mission analysis effort conducted during program included a review of the launch environment (i.e., the booster flight) and the target engine operating duty cycles and operating environments. This was done to

TABLE 1. LAUNCH AND FLIGHT ENVIRONMENT

Preliminary*

Heating, F	
Prelaunch	60 at 60% relative humidity 80 at 45% relative humidity
Launch (at shroud--maximum*)	~1400
Re-entering (at shroud--maximum*)	~240
Pressure, psia	
Launch	14.7 to 0
Operation	~0
Longitudinal and Lateral Acceleration, g	
Launch	<10 longitudinal ~3 lateral
Dynamic Environment, Hz	
Vibration	36 to 2000 at 0.1 (g rms) 2/Hz (nonshock-mounted items)
Shock	35 to 450 at ±22 g shock spectrum (Q = 10); Q = 10 selected from Rocketdyne experience with engine and tank mount structure
Primary Structure Loads, g	
Lateral	±3
Longitudinal	<10
Impact, ft/sec	≥25

*Based on Boeing specification D2-26240-1 identify any special requirements that existed, and provide basic design information for the final design analysis and design layouts. Investigations were conducted on the impact conditions to specify, in as detailed a manner as possible, any special design requirements to minimize possible damage.

Another mission-oriented function assessed, relative to the TEM-3 and HPTEM-3 missions, is time between firings. Because the LR101-NA-7 engine is regeneratively cooled with the valve upstream of the coolant jacket, the requirement for a gas purge before restart was assessed during Task III. The initial design did not include purge based on experience gained on the OME Reusable Thrust Chamber, where the engine was restarted with off times from 0.3 to 856 seconds. LR101-NA-7 restart sensitivity was also investigated under Task II. Such factors as attitude control operations (which affect the propellant tank sloshing and thus special antisloshing requirements), aerodynamics heating, vibration, and g-levels were specified.

PROPELLANT PRESSURIZATION AND FEED SYSTEM

The objective of this was to design a propellant pressurization feed system common to both the RS-1401 and LR101-NA-7 engines, and to select tanks and pressurization control components to meet the operational requirements of the target engine system.

The propellant tankage, pressurization, and feed systems were designed for compatibility with either engine system and used common design and assembly wherever possible. The systems were designed to function at the nominal operating point for a total mission accumulated burn time of approximately 25 seconds in the high-thrust version. Subsystem designs made maximum use of existing, off-the-shelf component hardware such as tanks, valves, or regulators, etc., without modification.

It should be noted that complete feed system commonality for the two engines could not be accomplished because of engine propellant valve considerations. Since the LR101-NA-7 propellant valve was pneumatically actuated, regulated GN_2 was required from the feed system pressurization system to the valve. This was not required on the electrically activated RS-1401 valve, which is pressure-sensitive because it cannot open against propellant inlet pressures exceeding 350 psia.

Transient performance capabilities (i.e., start and shutdown) were investigated to the extent necessary to ensure that a predictable and safe flight operation would result.

Propellant Loading

Propellant loading for TEM-1 and -2 was based on a mission duty cycle of six burns for a total duration (valve open signal to valve close signal) of 119 seconds, while TEM-3 loading used a mission duty cycle of five burns for a total of 25 seconds. To ensure that these duration requirements were met, the worst-case operating conditions were defined and propellant quantities adjusted accordingly. Once the engine balance point had been established from system hot-fire data, the potential variation in propellant flowrates for flight would be due to regulator pressure and propellant temperature variations. The constraint selected for the regulator pressure was $\pm$25 psi from nominal. Propellant temperature limits were selected at 30 F minimum, 110 F maximum. An additional requirement was that in the event the engine propellant valve failed to close, oxidizer would deplete first, thereby eliminating the occurrence of a chamber over-temperature condition.

It should be noted that the off-nominal operating performance was predicted from the TEM nonlinear computer model and TEM hot-fire data.

TEM-1 Loading. The oxidizer load is determined for the maximum oxidizer flowrate. This condition occurs at maximum regulator pressure and minimum propellant temperature, i.e., +25 psi and 30 F. The calculated oxidizer flowrate at this off-nominal point is 0.7223 lb/sec. For a 120-second duration (119-second duty cycle plus 1 second for timer variance), the oxidizer load is:

$$120 \times 0.7223 = 86.7 \text{ pounds}$$

The fuel load is now determined subject to the constraint of oxidizer depletion. Satisfying this constraint requires the minimum engine mixture ratio to be defined. The minimum mixture ratio occurs at the minimum regulator pressure and maximum propellant temperature, i.e., -25 psi and 110 F. A mixture ratio of 1.545 is calculated for this off-nominal operating point. The fuel load is then determined as:

$$\frac{86.7}{1.545} = 56.1 \text{ pounds}$$

<u>TEM-2 Loading.</u>

Maximum oxidizer flowrate:	0.7187 lb/sec
Oxidizer load:	120 x 0.7187 = <u>86.2</u> pounds
Minimum mixture ratio:	1.596
Fuel load:	$\frac{86.2}{1.590}$ = <u>54.0</u> pounds

<u>TEM-3 Loading.</u>

Maximum oxidizer flowrate:	3.083 lb/sec
Oxidizer load:	26 x 3.083 = 80.2 pounds
Minimum mixture ratio:	1.688
Fuel load:	80.2/1.688 = 47.5 pounds

Tables 2 through 4 present the propellant residuals calculated for the regulator and propellant operating limits previously mentioned. In addition, the burn duration, in the event of a depletion, is presented.

TABLE 2. TEM-1 PROPELLANT LOADINC

(OXIDIZER: 86.7 POUNDS, FUEL: 56.1 POUNDS)

Operating Limits		Duty Cycle			Depletion		
		Propellant Residuals, pounds		Duration, Seconds	Propellant Residuals, pounds		Duration, Seconds
Regulator Pressure, psi	Propellant Temperature, F	N_2O_4	MMH		N_2O_4	MMH	
+25	30	0.75	1.23	119 ↓	0	0.75	120.0
+25	110	2.98	2.03		0	0.01	123.2
Nominal	70	6.70	4.74		0	0.44	129.0
-25	30	10.94	7.64		0	0.64	136.2
-25	110	12.85	8.30		0	0.0	139.7

TABLE 3. TEM-2 PROPELLANT LOADING

(OXIDIZER: 86.2 POUNDS, FUEL 54.0 POUNDS)

Operating Limits		Duty Cycle			Depletion		
		Propellant Residuals, pounds		Duration, Seconds	Propellant Residuals, pounds		Duration, Seconds
Regulator Pressure, psi	Propellant Temperature, F	N_2O_4	MMH		N_2O_4	MMH	
+25	30	0.67	1.06	119 ↓	0	0.66	120.0
+25	110	2.91	1.81		0	0	123.2
Nominal	70	6.67	4.54		0	0.39	129.0
-25	30	10.91	7.46		0	0.73	136.2
-25	110	12.81	8.08		0	0.05	139.8

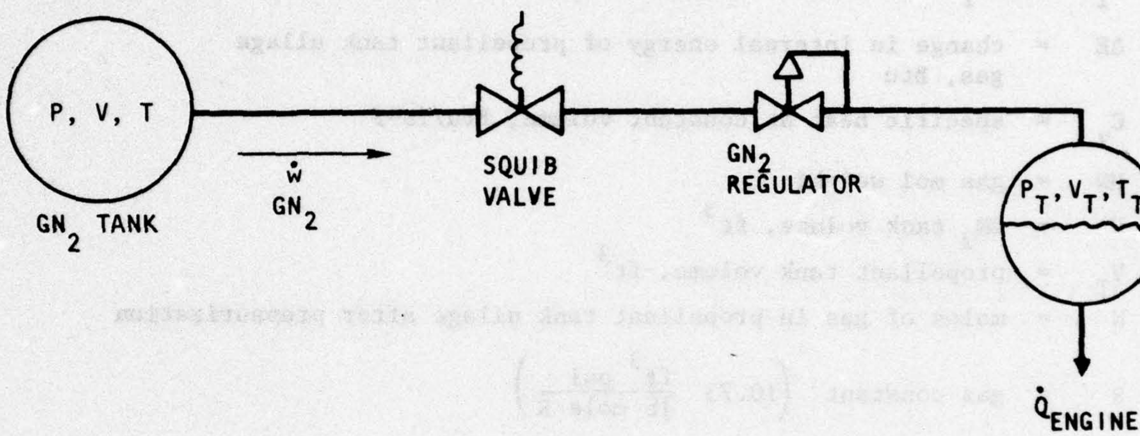
TABLE 4. TEM-3 PROPELLANT LOADING

(OXIDIZER: 80.2 POUNDS, FUEL: 47.5 POUNDS)

Operating Limits		Duty Cycle			Depletion		
		Propellant Residuals, pounds			Propellant Residuals, pounds		
Regulator Pressure, psi	Propellant Temperature, F	N_2O_4	MMH	Duration, Seconds	N_2O_4	MMH	Duration, Seconds
+25	30	3.12	2.38	25	0	0.54	26.0
+25	110	4.52	2.67	↓	0	0	26.5
Nominal	70	6.65	4.20	↓	0	0.22	27.3
-25	30	8.90	5.80	↓	0	0.59	28.1
-25	110	10.15	6.02	↓	0	0.02	28.6

Pressurization Requirements

A computer model of the pressurization system was constructed to assist in the selection of the system volume and operating pressure. A schematic of the pressurization model is shown below:



where:

$$V_T = V_{MMH\ tank} + V_{NTO\ tank} \quad \text{(total propellant tank ullage)}$$

$$\dot{Q}_{engine} = \dot{Q}_{NTO} + \dot{Q}_{MMH} \quad \text{(total engine volumetric flow)}$$

For the initial pressurization,

$$P_1 = P_o - \frac{(\Delta E)R}{(MW)\ V\ C_v} \tag{1}$$

$$T_1 = T_o \left(\frac{P_1}{P_o}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{(isentropic expansion)} \tag{2}$$

$$N = \frac{V}{R}\left[\frac{P_o}{T_o} - \frac{P_1}{T_1}\right] \tag{3}$$

$$T_T = \frac{P_T\ V_T}{NR} \tag{4}$$

where:

P_o = initial GN_2 tank pressure, psia

T_o = initial GN_2 tank temperature, R

P_1 = GN_2 tank pressure after pressurization

T_1 = GN_2 tank temperature after pressurization

ΔE = change in internal energy of propellant tank ullage gas, Btu

C_v = specific heat at constant volume, Btu/lb-F

MW = gas mol weight

V = GN_2 tank volume, ft^3

V_T = propellant tank volume, ft^3

N = moles of gas in propellant tank ullage after pressurization

R = gas constant $\left(10.73 \ \frac{ft^3 \ psi}{lb \ mole \ R}\right)$

P_T = propellant tank run pressure, psia

T_T = propellant tank temperature after pressurization, R

The following set of equations was used to calculate GN_2 tank pressures and flowrates during engine firing:

$$P = P_1 - \frac{\dot{Q} \, P_T \, \gamma \, t}{V} \tag{5}$$

$$T = T_1 \left(\frac{P}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \tag{6}$$

$$\dot{w} = \frac{\dot{Q} \ P_T \ (MW)}{R \ T} \tag{7}$$

where:

P = GN_2 tank pressure at time (t), psi

T = GN_2 tank temperature at time (t), R

$\dot{W}$ = GN_2 flowrate at time (t), lb/sec

γ = Specific heat ratio

The requirement to maintain commonality between the two systems dictated that pressurization system sizing be predicated on TEM-3 operation. The following items were established to proceed with the pressurization system analysis:

1. Propellant loading: 90 pounds of NTO and 56 pounds of MMH
2. TEM-3 propellant tank run pressure: 680 psia
3. Propellant flowrates: 3.077 lb/sec of NTO and 1.923 lb/sec of MMH
4. GN_2 purge for vernier engine
5. Propellant tank volume: 3017 $in.^3$

Items 1 through 4 were based on initial estimates and assumptions prior to the acquisition of test data on the vernier engine NTO/MMH propellant conversion.

Selection of the Atlas fuel start tank as the TEM propellant tanks along with the baseline propellant loading established the initial propellant tank ullage volumes. The task was to select the initial GN_2 tank pressure (P_o) and volume (V) such that sufficient GN_2 regulator control margin was maintained to ensure stable propellant tank pressure, provide for a possible vernier engine purge requirement, and ensure residual propellant draining following the last engine burn. A minimum regulator control of ΔP of 120 psi was selected. The minimum GN_2 tank pressure at the last engine cutoff was determined to be 800 psia (120 + 680 psia) based on TEM-3 propellant tank pressures.

The pressurization model was used to evaluate the effects of GN_2 tank volume and initial GN_2 tank pressure on gas margin at last cutoff. A sample of the computer output is presented in Table 5. Results depicting GN_2 tank pressure after the last burn as a function of initial GN_2 tank pressure and tank volume are shown in Fig. 1. As noted in Fig. 1, the design point selected was 3000 psia initial pressure with

TABLE 5. SAMPLE COMPUTER OUTPUT

```
RUN


PRESS1     14:56  RI T/S MAR 30, 1977

INITIAL GN2 TANK PR= 3000
INITIAL GN2 TANK TEMP= 70
INITIAL PROP TANK PR= 13.8
PROP TANK RUN PR= 680
MMH LOAD= 56
NTO LOAD= 90
MMH TANK ULLAGE VOL= 1243.07
NTO TANK ULLAGE VOL= 1292.26
GN2 TANK VOL= 3000.
MMH FLOW= 1.88563
NTO FLOW= 3.017

GN2 TANK PR POST PRESS.= 2436.99
GN2 TANK TEMP POST PRESS.= 39.442
PROP TANK GN2 TEMP POST PRESS.= 255.695
INITIAL GN2 MASS 25.6437
FINAL GN2 MASS 22.1057
DELTA GN2 MASS 3.53803
LEAK MASS 0
DELTA GN2 PRESS 563.011

TIME    GN2 PR   GN2 TP    GN2 FLOW   PROP TNK TP    MMH LEVEL    NTO LEVEL

 0      2437.    39.44     .2417      255.7          10.02        9.823
REG IN PR= 2430.
REG PERCENT OPEN= 10.36
 5      2250.    28.21     .2472      199.9          8.832        8.675
REG IN PR= 2242.
REG PERCENT OPEN= 11.36
 10     2064.    16.29     .2534      163.5          7.639        7.517
REG IN PR= 2055.
REG PERCENT OPEN= 12.55
 15     1877.    3.573     .2604      136.9          6.396        6.307
REG IN PR= 1867.
REG PERCENT OPEN= 14.
 20     1691.   -10.08     .2683      115.6          5.03         4.977
REG IN PR= 1679.
REG PERCENT OPEN= 15.8

 20
MMH RESIDUAL= 579.3
NTO RESIDUAL= 568.4
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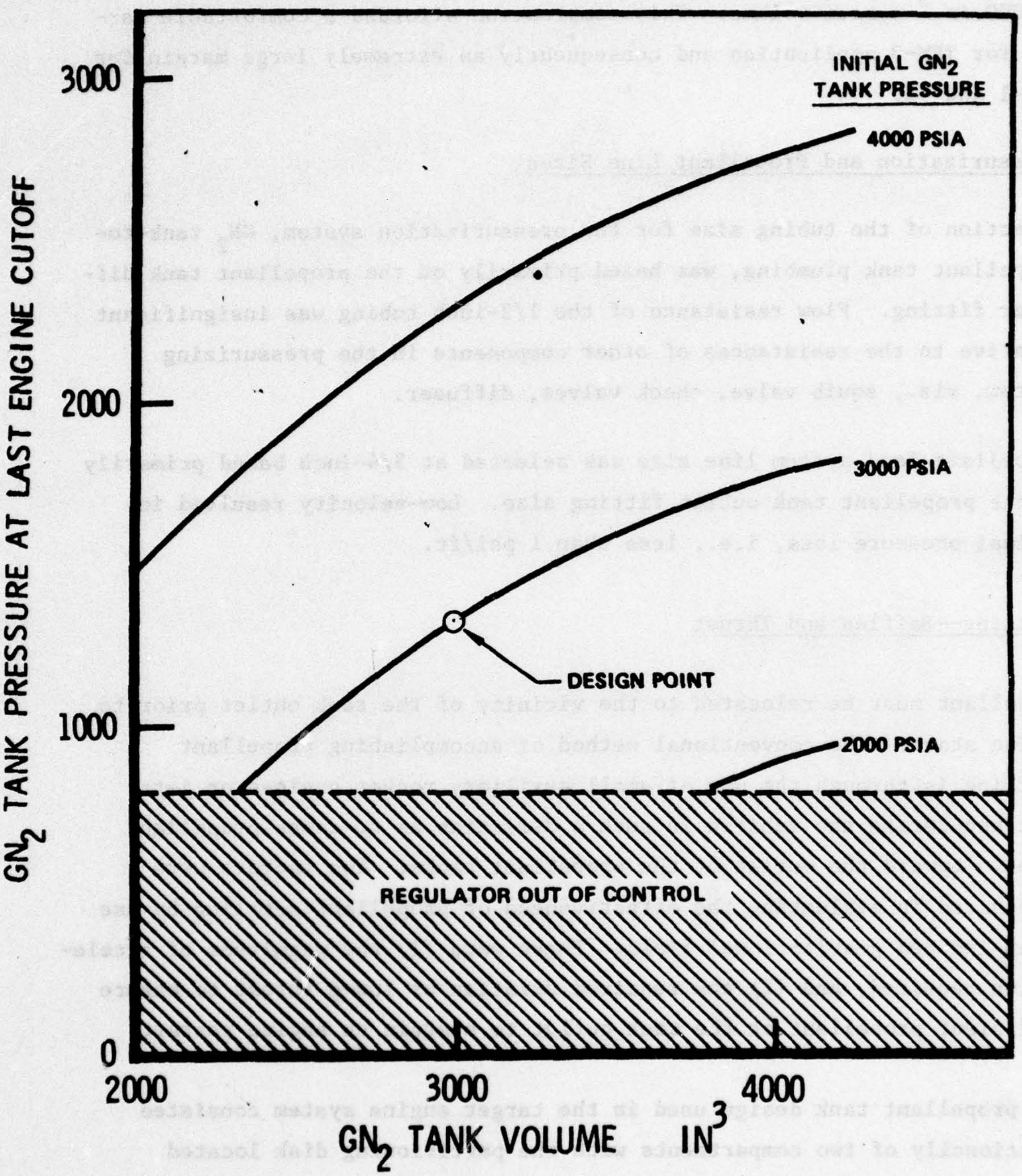

Figure 1. TES Pressurization Requirements

a 3000-in.^{3} system volume. This combination afforded a comfortable margin for TEM-3 application and consequently an extremely large margin for TEM-1 and -2.

Pressurization and Propellant Line Sizes

Selection of the tubing size for the pressurization system, GN_2 tank-to-propellant tank plumbing, was based primarily on the propellant tank diffuser fitting. Flow resistance of the 1/2-inch tubing was insignificant relative to the resistances of other components in the pressurizing system, viz., squib valve, check valves, diffuser.

Propellant feed system line size was selected at 3/4-inch based primarily on the propellant tank outlet fitting size. Low-velocity resulted in minimal pressure loss, i.e., less than 1 psi/ft.

Settling--Baffles and Thrust

Propellant must be relocated to the vicinity of the tank outlet prior to engine start. The conventional method of accomplishing propellant settling is through the use of small auxiliary rocket engines or jets that accelerate the vehicle in such a direction as to cause propellant to move toward the outlet of the propellant tanks. Two factors were considered in evaluating the effectiveness of propellant settling by use of an induced gravitational field. These were (1) the magnitude of acceleration required, and (2) the required duration of low-g thrust to ensure sufficient propellant at the tank outlet to sustain an engine restart.

The propellant tank design used in the target engine system consisted functionally of two compartments with the partitioning disk located approximately a half tank radius from the tank outlet. The edge of the disk is in a contact fit with the inside surface of the tank and the fluid flow between the two compartments must pass through four rectangular holes punched out in the partitioning disk (Fig. 2 and 3).

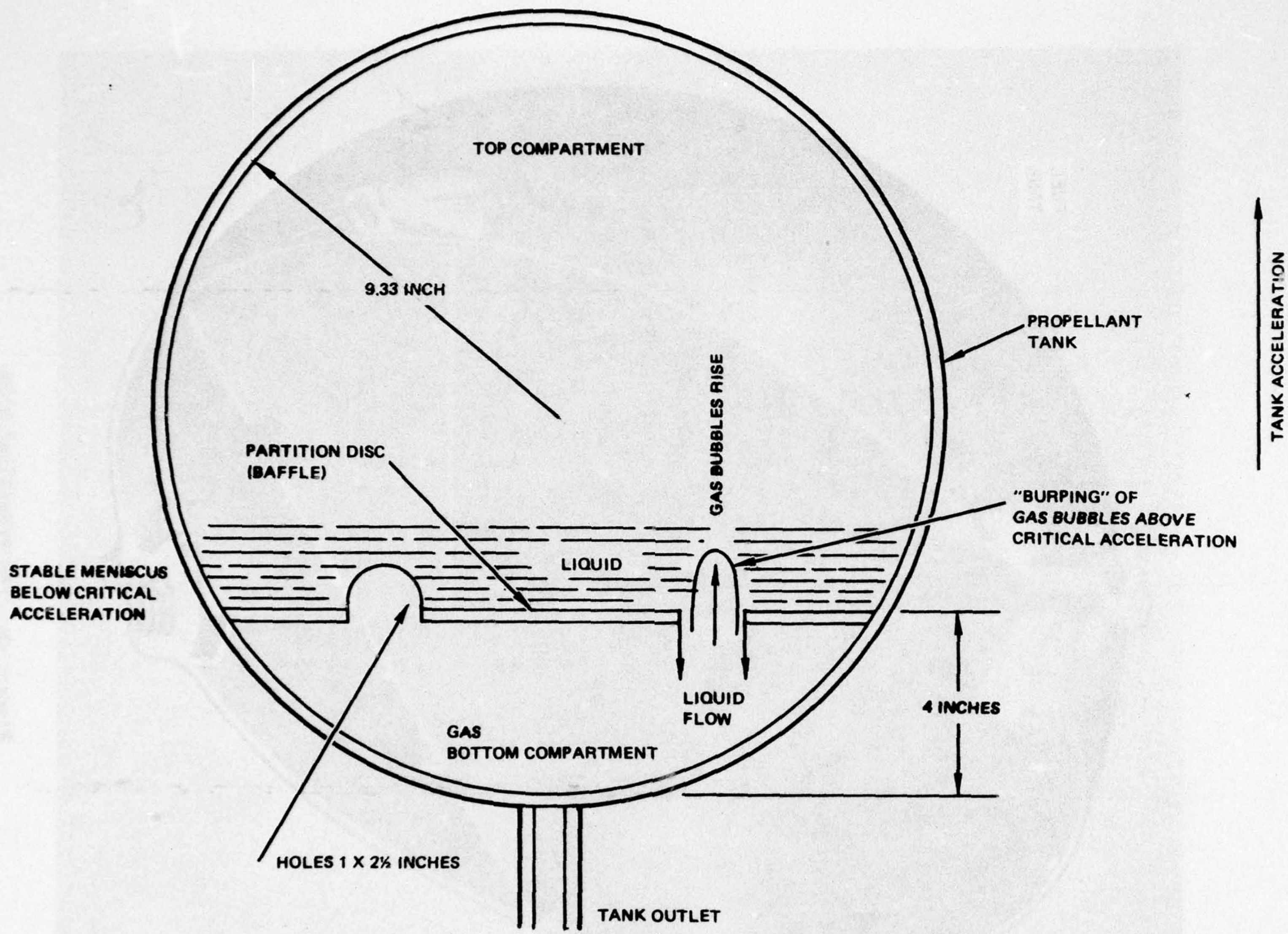

Figure 2. Gas-Liquid Interfaces (Menisci) Across Baffle Holes Below and Above Critical Settling Acceleration

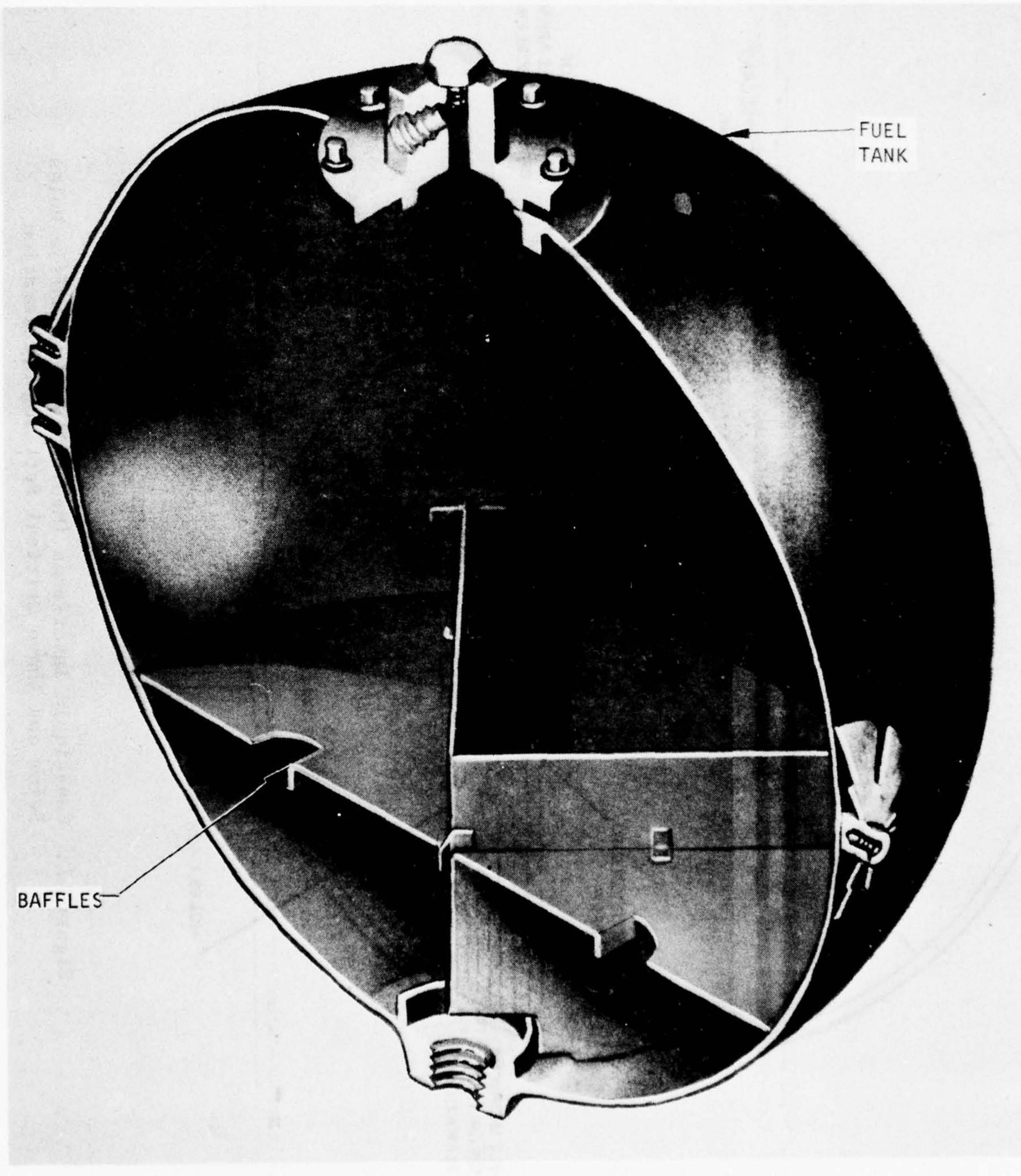

Figure 3. TES Propellant Tank

Critical Acceleration. Vehicle disturbances or events such as attitude engine firings, liquid sloshing during powered flight, springback or recoil effect of vehicle spring members after booster thrust termination, mass transfer, or ejection may result in dislocation of the propellant from the bottom compartment.

The worst case of propellant dislocation is assumed to be as shown in Fig. 2 with all or the bulk of the liquid propellant located in the top compartment and ullage gas in the bottom compartment. Stable liquid/gas interfaces or menisci, as shown in Fig. 2, will be formed across the rectangular holes in the partitioning disk under prevailing zero or low-g conditions after vehicle disturbances have subsided. There exists a critical minimum value of acceleration (in forward direction) below which the menisci will remain stable and no gas will penetrate the interfaces and flow into the top compartment to displace the liquid. This value of acceleration is dependent on the hole dimensions, gas/liquid surface tension, and gas/liquid density difference. The phenomenon can be readily observed by noting that in the earth-gravity environment a water column can be held up in a 1/4-inch-diameter soda straw that is closed at the top, but will invariably drain out of an inverted drinking glass or an inverted tube larger than 1/2-inch in diameter.

The critical acceleration is determined by the critical Bond number, which is a dimensionless number bearing the ratio of gravity force to surface tension force, and is given in Ref. 1 as:

$$Bo_c = \frac{\rho a_c D^2}{\sigma} = 3.369 \qquad (1)$$

---

1. Abramson, H. Norman: The Dynamic Behavior of Liquids in Moving Containers, NASA SP-106, 1966.

where

a_c = critical acceleration

ρ = liquid/gas density difference

D = diameter of pore

σ = gas/liquid surface tension

The critical Bond number for circular pores and wetting liquids such as propellants MMH and NTO with contact angles close to zero can be analytically computed (Ref. 1) and is equal to 3.369. For noncircular pores, the computation becomes much more involved. In this case, the smaller dimension of 1 inch of the rectangular hole (1 by 2-1/2 inches) is used to determine the critical acceleration that would give a more conservative value. For the fuel tank (at 75 F) with 1-inch pores in the disk, $\rho = 0.0329$ lbm/in.^{3}, and $\sigma = 0.000285$ lbf/in., the critical acceleration is

$$a_c = 11.26 \text{ in./sec}^2 = 0.029 \text{ g}$$

For the oxidizer (NTO) at 75 F, $\rho = 0.0527$ lbm/in.^{3}, and $\sigma = 0.000146$ lbf/in., the critical acceleration is

$$a_c = 3.60 \text{ in./sec}^2 = 0.009 \text{ g}$$

The acceleration obtained by firing the settling rockets must exceed the critical value before the ullage gas can break through the menisci and displace the liquid from the top compartment. The maximum thrust available for propellant settling is 20 lbf. This will only provide a 0.020-g acceleration (based on a vehicle weight of 1000 lbm), which is lower than the critical value. One way of reducing the critical acceleration would be to increase the hole size in the partition disk. Increasing the minimum dimension to 2 inches would reduce the critical acceleration to 0.007 g for the fuel tank.

Propellant Settling Flow. Once the settling acceleration exceeds the meniscus stability level, the gas starts to flow up in the center of the hole, while the liquid flows down through the hole around the central gas core in annular stream. No rigorous theoretical treatment of this hydrodynamic problem is known. Davis and Taylor (Ref. 2) derived the following equation for the rate of rise of a gas bubble (gas/liquid interface velocity) in liquid in a cylindrical tube from the potential theory neglecting the effects of surface tension and viscosity:

$$Fr = V_1/\sqrt{aD} = 0.329 \quad (2)$$

where

Fr = Froude number

V_1 = velocity of gas/liquid interface

D = tube ID

a = acceleration

Both surface tension and viscosity will result in a decreased liquid flowrate. Empirical correlation was made from tests conducted by Davis and Taylor (Ref. 2) to show the effect of decrease in Froude number at low Bond numbers. At high Bond numbers, the Froude number approaches 0.329, as obtained in the above equation.

The effect of viscosity is generally small with liquids such as NTO and MMH. For highly viscous liquids, an approximate Reynold number correction f(Re) was obtained from Goldsmith and Mason (Ref. 3). Thus, the

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2. Davis, R. M., and G. Taylor: The Mechanics of Large Bubbles Rising Through Liquids in Tubes, Proceedings of the Royal Society, London, England, Series A, Vol. 220, 1949-1950.
3. Goldsmith, H.L., and S. G. Mason: "The Movement of Single Large Bubbles in Closed Vertical Tubes," Journal of Fluid Mechanics, Vol. 14, Part I, Sept. 1962.

liquid settling equation as a function of Bond number and Reynolds number is:

$$Fr = \frac{V_1}{\sqrt{aD}} = 0.36 \left(1 - \frac{4.5}{Bo}\right) [f(Re)] \qquad (3)$$

Equation 3 is only empirically valid. It gives a critical Bond number of 4.5 as compared to 3.369 given in Eq. 1, when $Re = \infty$, $f(Re) = 1$, and $Fr = 0$. At $Re = \infty$, $f(Re) = 1$ and $Bo = \infty$, Eq. 3 gives a Froude number $Fr = 0.36$ as compared to $Fr = 0.329$ given in Eq. 2.

The volume rate of gas bubble Q rising into the top compartment is equal to the volume rate of liquid settling into the bottom compartment, and is given approximately by:

$$Q = \frac{\pi}{4} D^2 V_1$$

For NTO and MMH, the viscosity effect is small and $f(Re) \simeq 1$:

$$Q = 0.283 (aD)^{1/2} \left[D^2 - \frac{4.5\,\sigma}{a}\right] \qquad (4)$$

Thus, the settling rate for MMH through four 1-inch holes under an acceleration of 0.315 g during TEM-1 firing is given by:

$$Q = 0.283 (121.7 \times 1)^{1/2} \left[1^2 - \frac{4.5 \times 0.000285 \times 386}{0.0329 \times 121.7}\right] \times 4$$

$$= 10.9 \text{ in.}^3/\text{sec.}$$

Required TEM-1 MMH flow is ≈ 14 in.^{3}/sec. The analysis indicates that the hole size in the partition disk gives too high a critical acceleration and too low a settling rate for the rocket thrust available. If the minimum dimension of the hole is increased to 2 inches, then the critical acceleration (from Eq. 2) is:

$$a_c = 2.82 \text{ in./sec}^2 = 0.0073 \text{ g}$$

and the settling rate Q with a settling acceleration of 0.020 g or 7.72 in./sec^2 (from Eq. 4) is:

$$Q = 0.283 \; (7.72 \times 2)^{1/2} \left[2^2 - \frac{4.5 \times 0.000285 \times 386}{0.0329 \times 7.72} \right] \times 4$$

$$= 9.123 \text{ in.}^3/\text{sec}$$

and the settling rate Q during firing of TEM-1 is:

$$Q = 0.283 \; (121.7 \times 2)^{1/2} \left[4 - \frac{4.5 \times 0.000285 \times 386}{0.0329 \times 121.7} \right] \times 4$$

$$Q = 68.5 \text{ in.}^3/\text{sec}$$

The firing duration of the settling rocket should be long enough so that sufficient propellant can be accumulated to start the main target engine. Once the rocket engine is started, sufficient acceleration should be available to provide continuous propellant acquisition. Both propellant tanks were modified to incorporate the larger baffle hole size by eloxing a semicircle onto the existing rectangular cutout. Baffle hole size was approximately doubled (see Fig. 3).

Pressure/Flow Schedule

The design pressure and flow schedules for TEM-1, -2, and -3 are shown in Fig. 4 and 5, respectively. The targeted performance for TEM-1 and -2 was based on the acceptance test data for the RS-14 engines allocated to the program. Standard inlet pressures of 238 psia oxidizer and 239 psia fuel were targeted. Estimates of component pressure drops from the GN_2 regulator to propellant tanks and propellant tanks to valve inlets yielded the regulator out pressure of 270 psia. A GN_2 flowrate of 0.02 lb/sec was calculated to support the tank pressurization requirements for TEM-1 and -2.

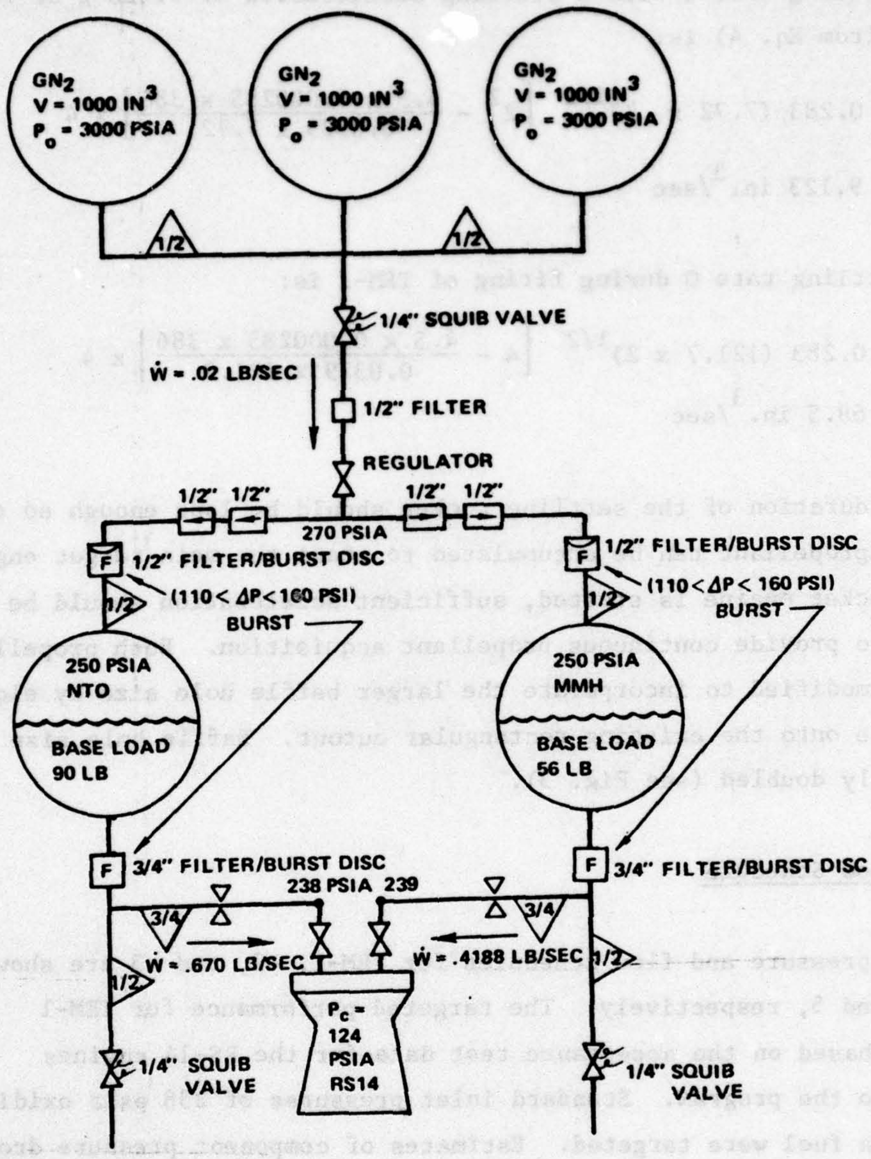


Figure 4. TEM-1, -2 Pressure/Flow Schedule (Design)

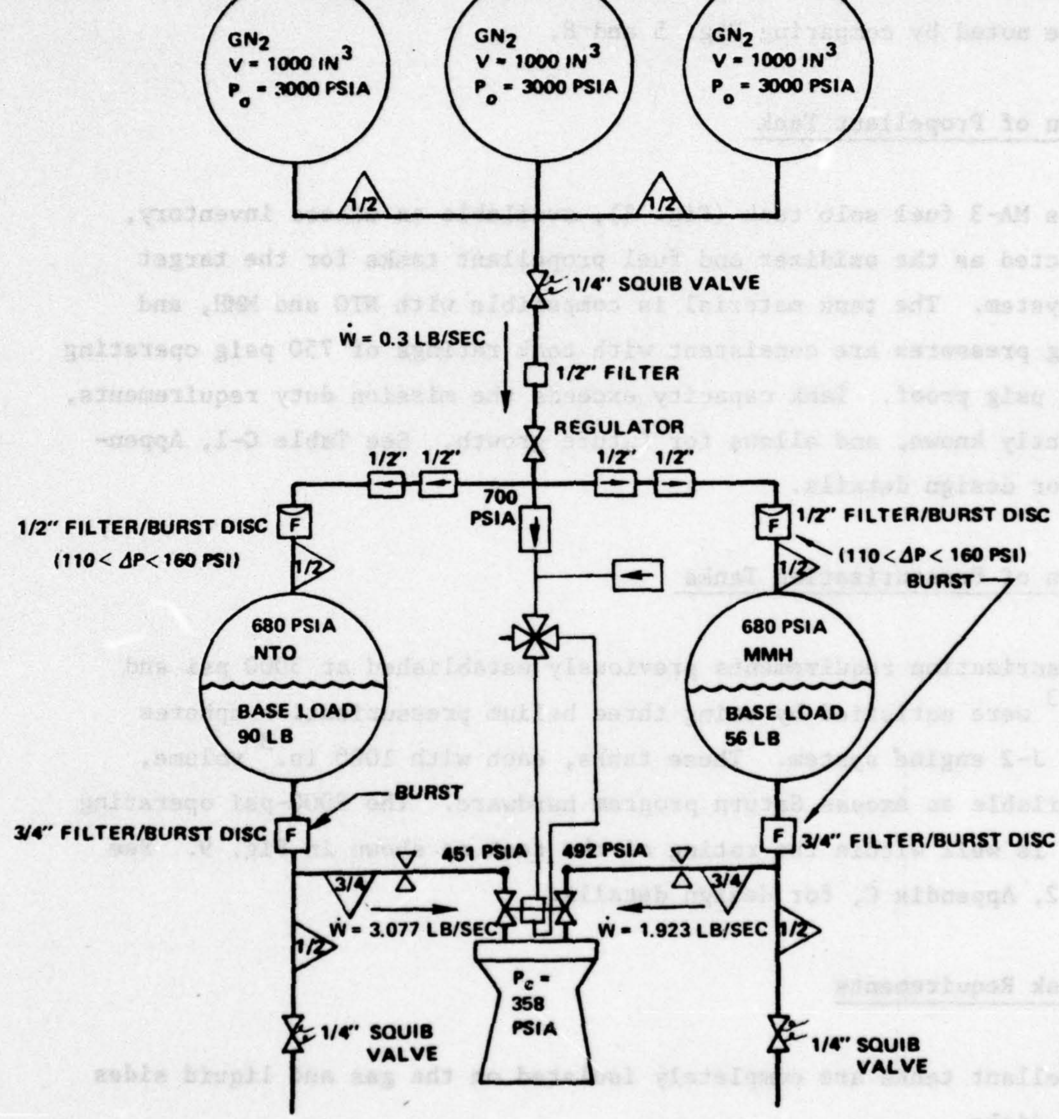


Figure 5. TEM-3 Pressure/Flow Schedule (Design)

Figures 6 and 7 depict the actual hot-fire test results for TEM-1 and -2, respectively. As can be seen, good agreement between design and test was achieved. Performance for the vernier engine was better than expected as can be noted by comparing Fig. 5 and 8.

Selection of Propellant Tank

The Atlas MA-3 fuel solo tank (Fig. 3), available as excess inventory, was selected as the oxidizer and fuel propellant tanks for the target engine system. The tank material is compatible with NTO and MMH, and operating pressures are consistent with tank ratings of 750 psig operating and 1020 psig proof. Tank capacity exceeds the mission duty requirements, as presently known, and allows for future growth. See Table C-1, Appendix C, for design details.

Selection of Pressurization Tanks

The pressurization requirements previously established at 3000 psi and 3000 $in.^3$ were satisfied by using three helium pressurization spheres from the J-2 engine system. These tanks, each with 1000 $in.^3$ volume, were available as excess Saturn program hardware. The 3000-psi operating pressure is well within the rating of the tank as shown in Fig. 9. See Table C-2, Appendix C, for design details.

Burst Disk Requirements

The propellant tanks are completely isolated on the gas and liquid sides by burst disks.

In establishing the burst pressure limits, one must consider the vapor pressure of the fluids, maximum acceleration of the boost vehicle before TEM is separated, and the minimum available regulator pressure.

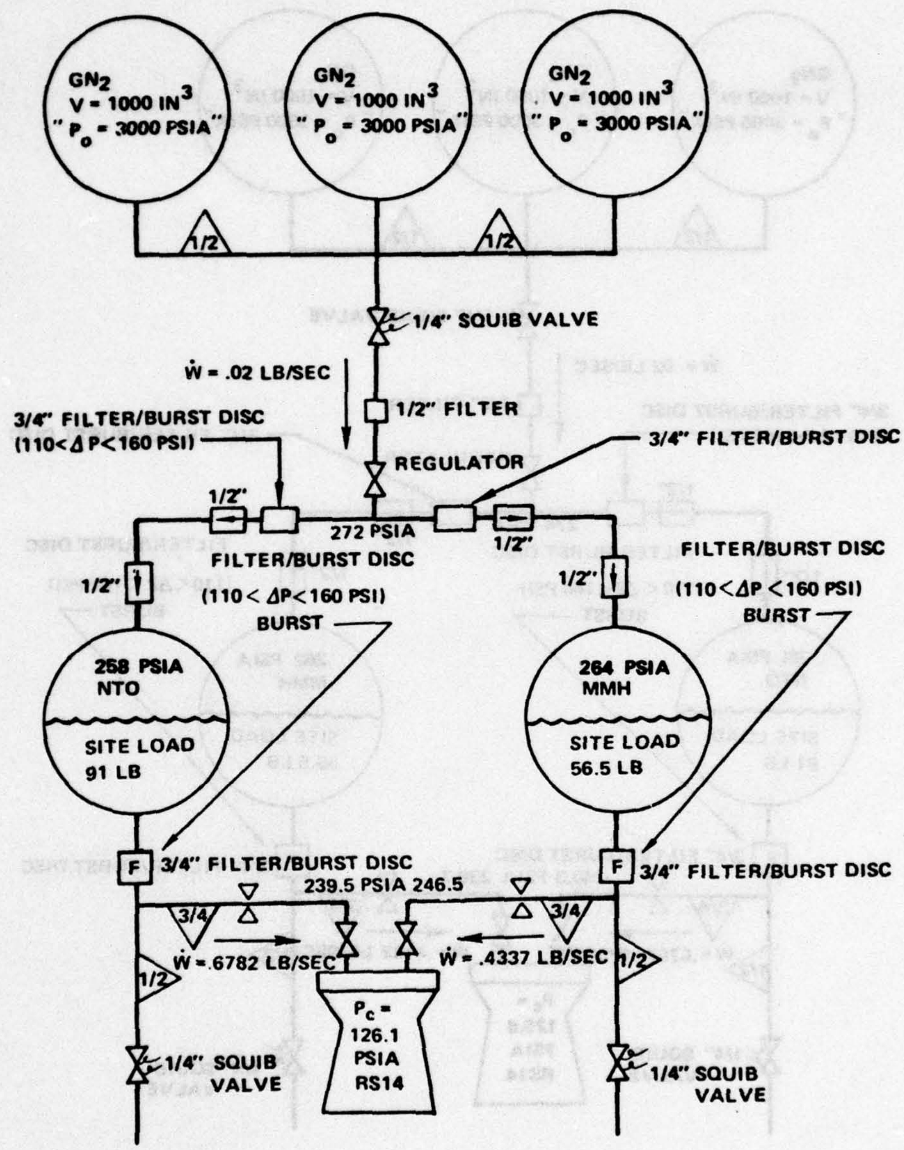


Figure 6. TEM-1 Pressure/Flow Schedule (Test Results)

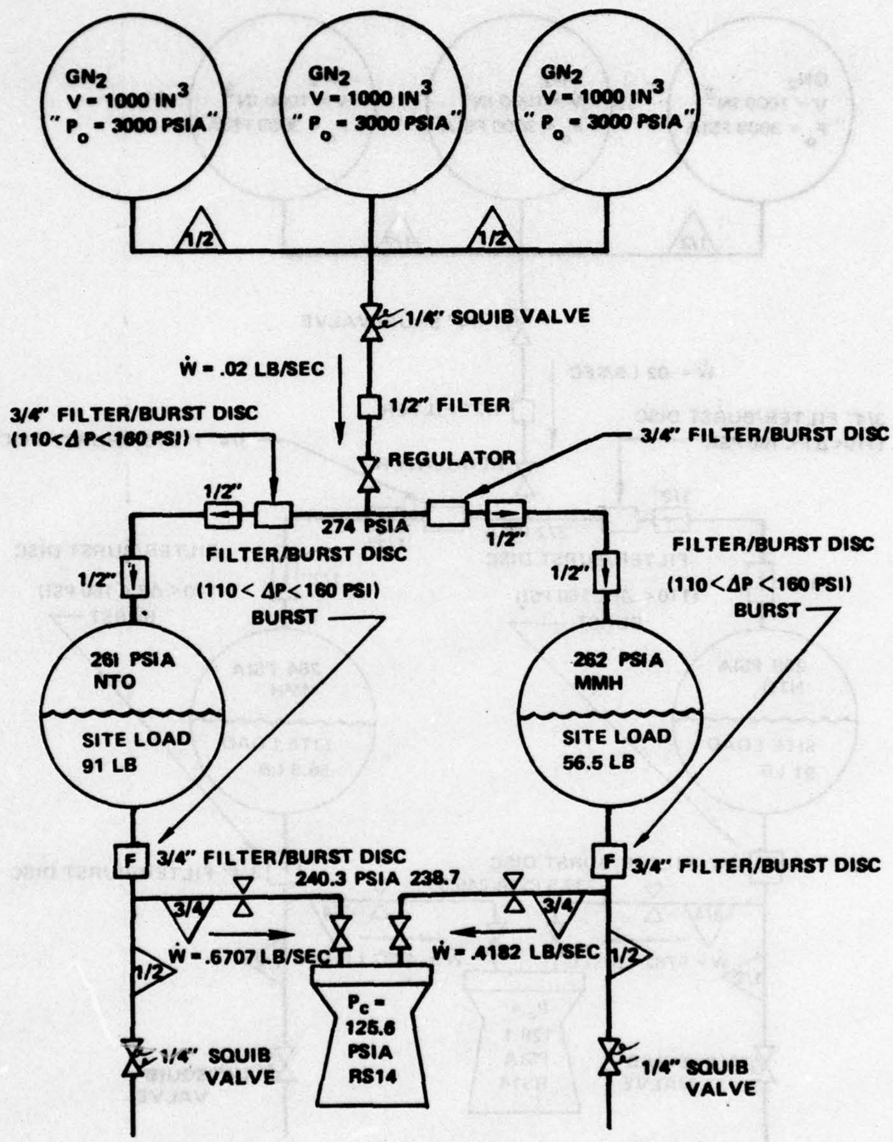


Figure 7. TEM-2 Pressure/Flow Schedule (Test Results)

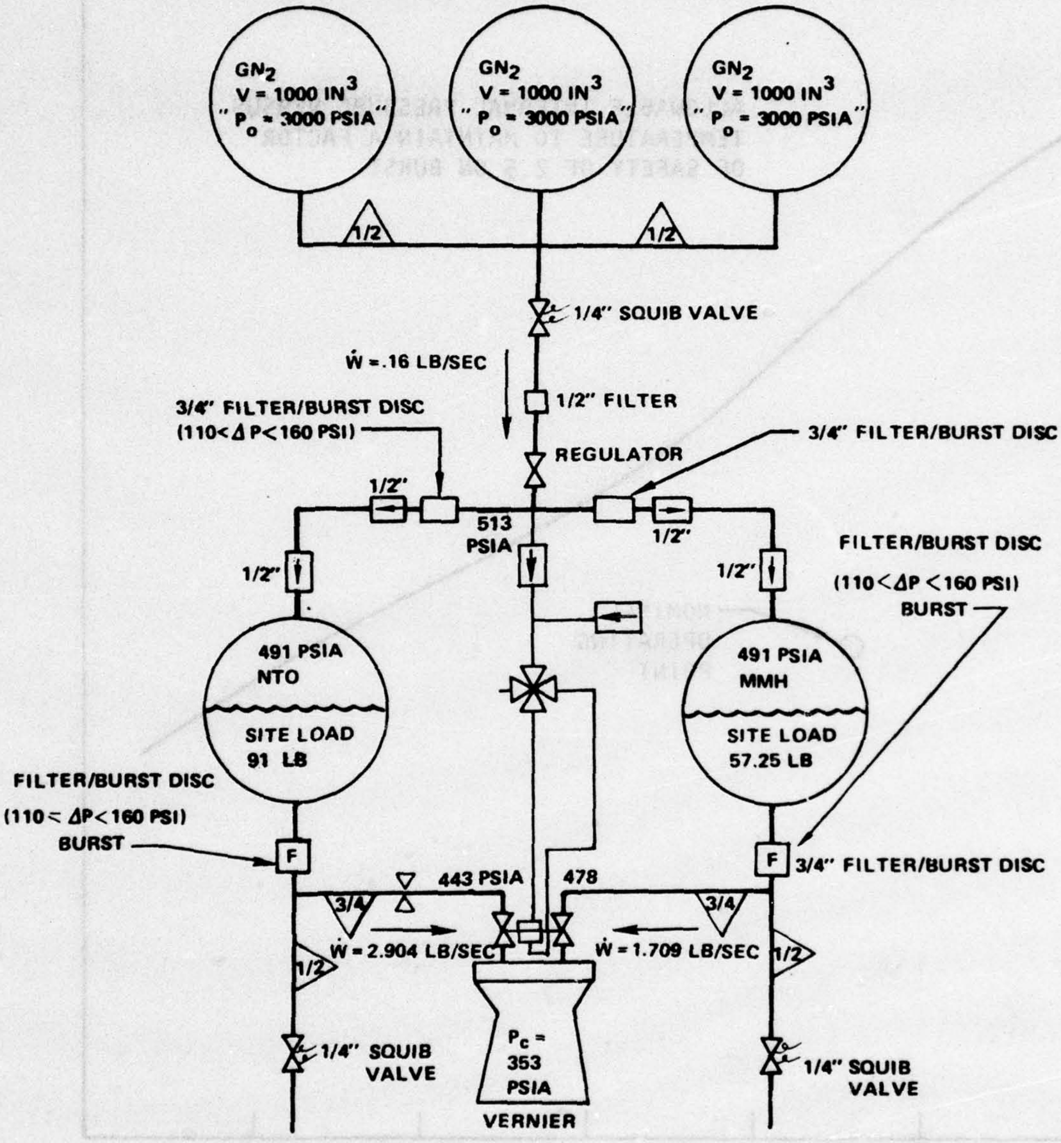


Figure 8. TEM-3 Pressure/Flow Schedule (Test Results)

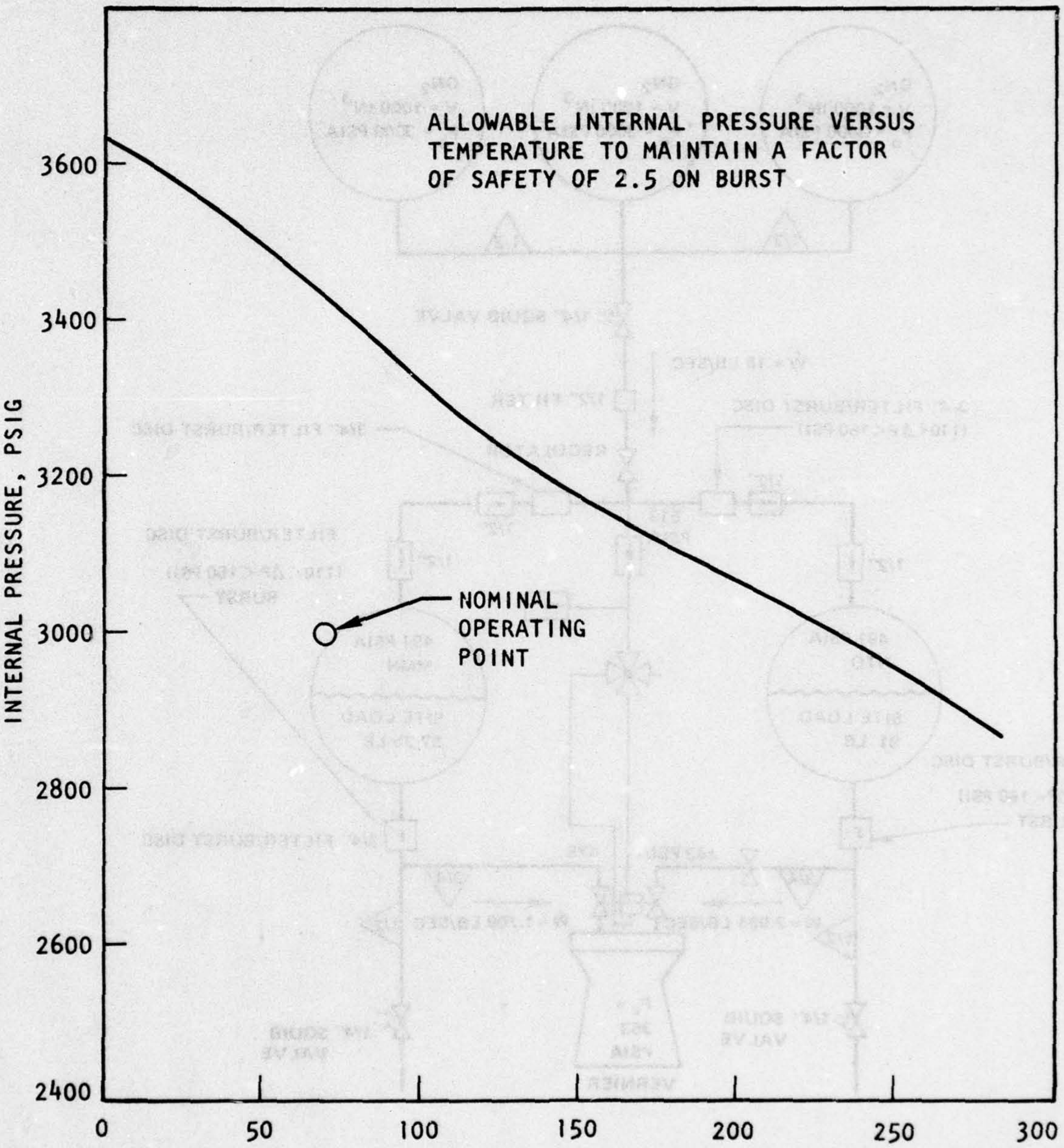


Figure 9. TEM GN_2 Tank

Because commonality of burst disks for TEM-1, -2, and -3 was desired, the minimum available regulator pressure was then established by TEM-1. Maximum vapor pressure occurs with NTO. The maximum acceleration of the boost vehicle was given as 10 g's. The maximum propellant temperature was assumed to be 150 F, corresponding to an NTO vapor pressure of 91 psia.

Minimum burst ΔP was that value which assured that the liquid-side disk would not rupture during the 10-g boost flight, thereby allowing propellants to prematurely migrate downstream to the propellant valves. The maximum burst ΔP was established to ensure that the disk ruptured when the propellant tanks were pressurized.

The minimum ΔP was therefore based on the liquid-side (downstream) disk pressure during the 10-g flight as follows:

$$\Delta P_{D/S\ disk} = (P_{vapor} + P_{head}) - P_{ambient}$$

for $T = 150$ F, $P_{vapor} = 91$ psia, density $= 81.6\ lb/ft^2$

$$P_{head} = \frac{81.16}{144}\ (2.3)\ (10) = 13\ psi$$

$$\Delta P_{D/S\ disk} = (91 + 13) - 0$$

$$\Delta P_{min} > 104\ psi$$

The maximum burst ΔP was based on the minimum expected propellant tank pressure, viz., TEM-1 operation, to ensure that the gas-side disk ruptured under conditions of maximum expected propellent vapor pressure.

$$P_{reg\ out} = 250\ psia$$

$$P_{vapor\ NTO} = 91\ psia$$

$$\Delta P_{u/s\ disk} = P_{reg\ out} - P_{vapor} = 250 - 91 = 159\ psi$$

$$\Delta P_{max} < 159\ psi$$

From the foregoing, the burst pressure range was specified as 110 to 160 psig. See Table C-3, Appendix C, for details of this component.

Selection of Control Components

The general requirements, functional characteristics, rationale for selection, and special testing of components used to build TEM-1, -2, and -3 are listed below.

Piston Regulator. A regulator was required for propellant tank pressurization at approximately 250 and 700 psig operating, with a supply pressure of 3000 down to 900 psig. Desired flow capacity was 0.02 to 0.3 lb/sec GN_2 in the regulated range. Considering these requirements, the Rocketdyne-designed 553700 regulator was selected because this unit was readily available and needed only removal of the heater assembly and reidentification to be ready for use. See Table C-4, Appendix C, for design features.

The main feature of this regulator was its ability to supply constant regulated pressure ($\pm$5 psig) with little effect from variations in supply pressure or rapidly fluctuating flow demands. The regulator had a history of successful use on Atlas, Jupiter, RS-27, and Thor flight programs, and did not require extensive special testing. Fast pressurization transient tests, which simulated functional characteristics under expected operating conditions, were performed using a fast-operating solenoid valve instead of the explosive-operated valve. These bench tests indicated that the regulator would perform satisfactorily in the system.

A manifold was designed to adapt the regulator and the relief valve to the system designated the Pneumatic Control Assembly (PCA), P/N TEP 1026 (regulator, relief valve, and manifold).

Relief Valve. The relief valve was required to prevent overpressure in the event of regulator failure. Functional capabilities were to be compatible with the selected regulator. The 550084 pilot-operated relief valve met all requirements without any modification. No special testing was required because of its successful use on Atlas, Jupiter, RS-27, and Thor engines. The unit was mounted on the same manifold as the regulator. Construction details are shown in Table C-5, Appendix C.

Explosive-Operated Valve. A valve was needed to initiate pneumatic system pressurization with remote actuation. The main function was to isolate the GN_2 tanks from the regulator. Because actuation was required only once per flight, an explosive-operated valve was acceptable. Other requirements were compatibility of pressure and capacity with the regulator. Considering flow and pressure requirements, the NA5-260180 valve manufactured by Conax was selected. Special proof pressure tests at 4500 psig were conducted to ensure satisfactory operation at 3000 psig. After these tests the valve was reidentified as TEP 1025.

The same valve also was used post-flight to dump propellants. Laboratory tests verified the flow capacity of this design for the dump requirement. Details of this valve are shown in Table C-6, Appendix C.

Check Valve. Series redundant check valves were required downstream of the regulator to prevent reverse propellant flow once the system was in operation. Cracking pressure of 8 psig max was specified and a flow capacity of 0.3 lb/sec at 10 psid max was desired. A Circle Seal 280T1-8TT check valve was selected for the application. The design did not require any special testing because of its successful history on other programs (Atlas, RS-27, and Thor). See Table C-7, Appendix C, for additional details.

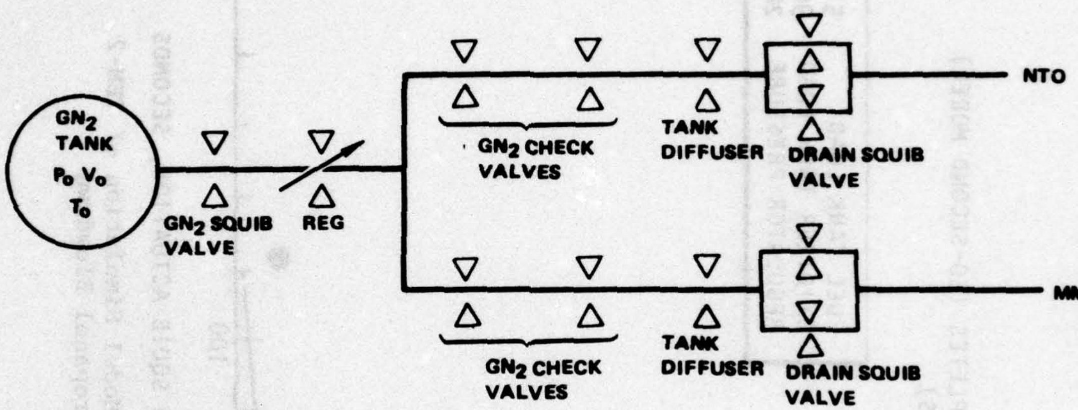
Filter. A filter compatible for service in GN_2, NTO, and MMH fluids was required. A 40-micron absolute rating was necessary, as well as a 3000-psig operating pressure capability. These requirements were satisfied by Wintec 14206-610 filter. No special testing was required because the same design has been successfully used in other applications. Details are shown in Table C-8, Appendix C.

Fill and Drain Valves. Propellant and pneumatic tank fill and drain valves were required, fabricated from materials compatible with GN_2, NTO, and MMH fluids, and with manual operation. Pyronetics 1831-15 and 1831-16 vlaves met these requirements. No testing was necessary because of their flight record on Viking and other programs. See Tables C-9 and C-10, Appendix C, for details.

Four-Way Solenoid Valve. The solenoid valve, which was needed for propellant valve control on TEM-3, was required to flow at least 135 scfm GN_2, with 100 psid maximum pressure drop at 750 psig supply pressure. The Rocketdyne-designed 555695 four-way solenoid valve met all these requirements without any modification, and required no special testing because of its successful history on other programs (Atlas, RS-27 and Thor). See Table C-11, Appendix C, for details.

BLOWDOWN CALCULATIONS

The TEM is equipped with a drain system to dump residual propellants and GN_2 after the final burn. The worst case in terms of time required to dump propellants would occur in the event the engine could not be started and the full propellant and GN_2 load had to be dumped. A computer model was developed to describe the drain system as depicted below:



A blowdown test conducted on TEM-2 using freon and isopropanol in the oxidizer and fuel tanks, respectively, showed good agreement with model results (Fig. 10).

Model predictions for TEM-1 and -3 based on flight propellant and GN_2 loading are depicted in Fig. 11 and 12 for the worst-case condition.

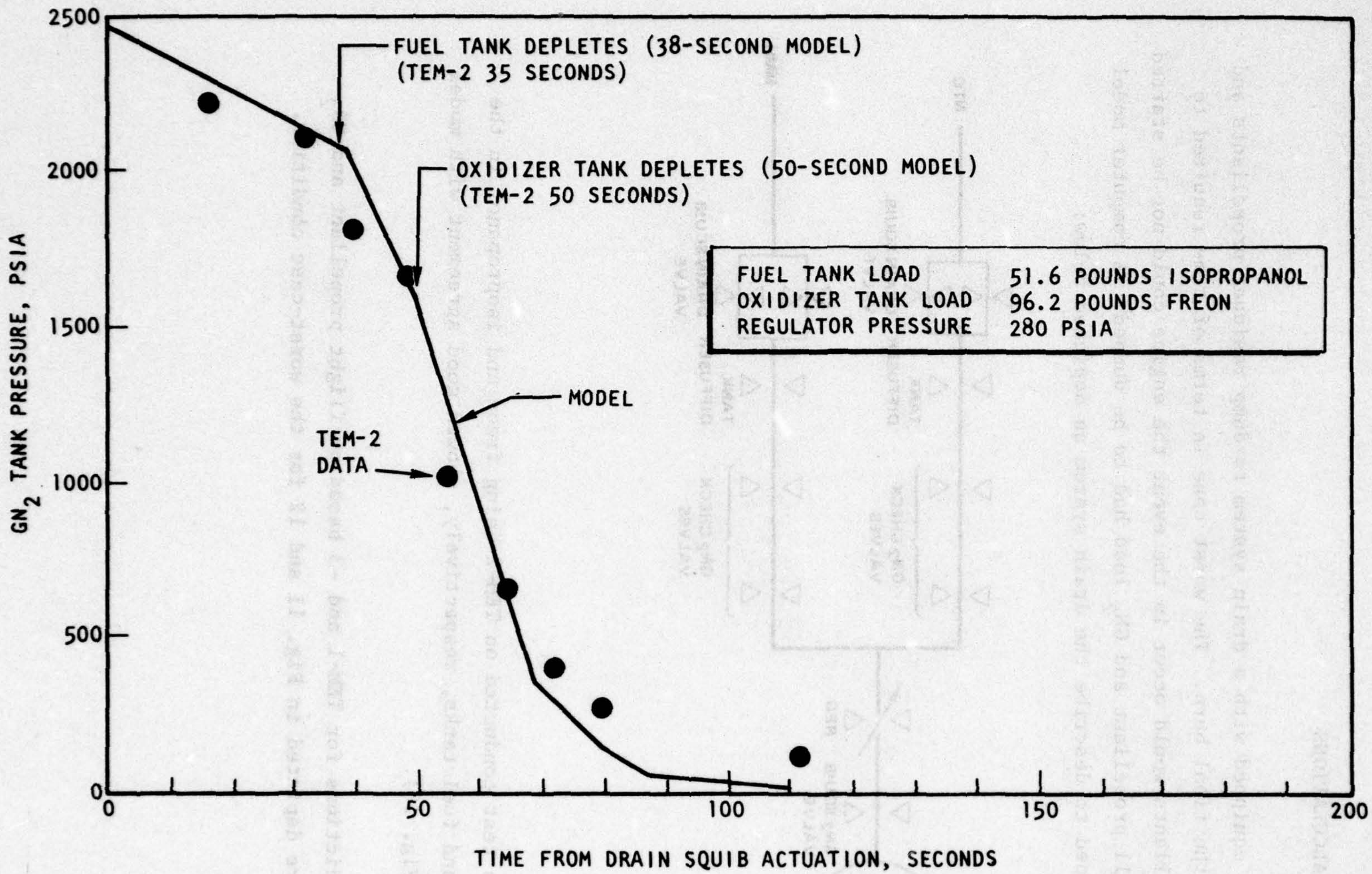


Figure 10. TEM Drain Model Simulation of TEM-2 Freon/Isopropanal Blowdown

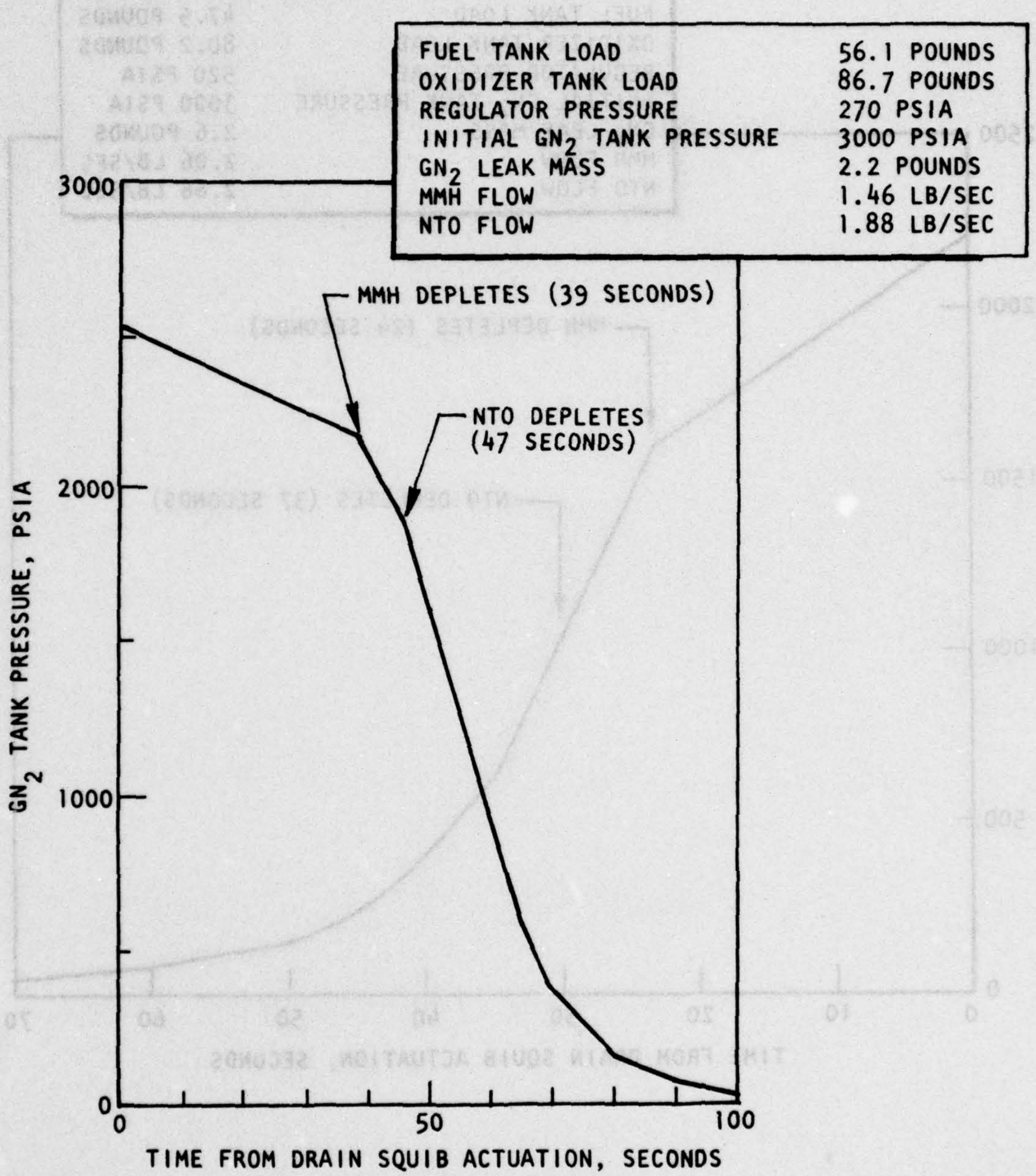


Figure 11. TEM-1 Propellant Dump (Model Simulation)

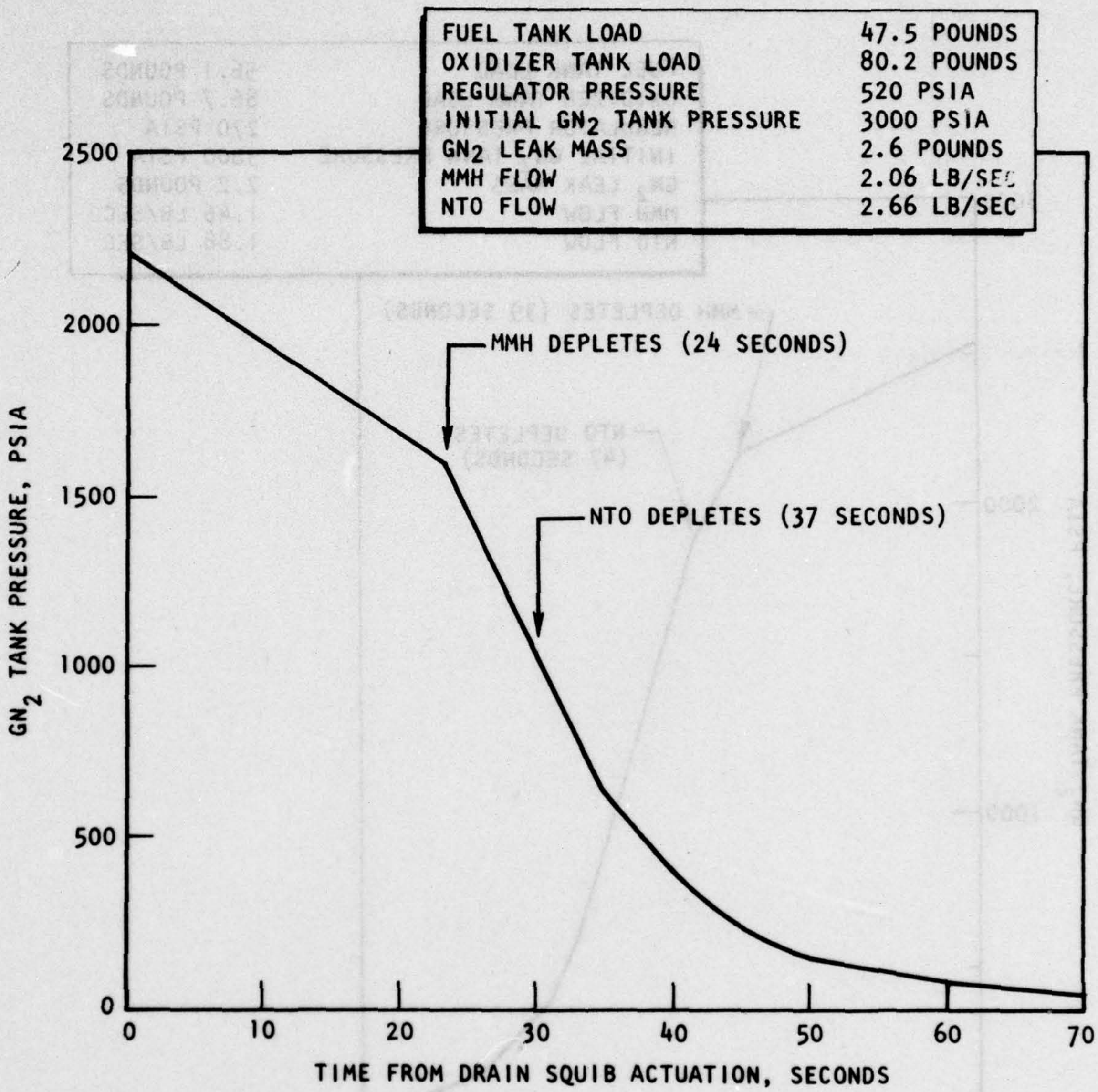


Figure 12. TEM-3 Propellant Dump (Model Simulation)

Sequencing

The sequencing requirements for TEM-1, -2, and -3 are common and depicted in Fig. 13. Upon separation from the boost vehicle, the TEM engine propellant valve is cycled open for a duration of 2 seconds and then closed. This allows ambient air trapped between the engine valve and propellant tank liquid-side burst disk to be dispelled. Following this event, the TEM settling thrusters are operated to provide a 0.02-g acceleration for 10 seconds to settle the propellants. At 5 seconds from the start of propellant settling, sufficient propellant is settled to the tank bottom to permit tank pressurization. The TEM GN_2 squib is then fired and settling continues for 5 additional seconds, thereby allowing the pressurization transient to stabilize before first engine start is initiated. Engine start should be initiated within 0.1 second of the settling thruster cutoff. Subsequent to the first engine start, 5 seconds of settling (providing 0.02 g) is required prior to each engine start, with engine start occurring within 0.1 second of settling thruster cutoff. Following the last engine cutoff, the drain squib will be energized to purge residual propellants and GN_2 from the TEM.

It should be noted that during the interval of propellant settling, no attitude control system firing should be initiated which would negate the propellant settling acceleration. The required acceleration of 0.02 g represents a resultant acceleration along the axis of the vehicle in the direction to cause the propellants to settle at the propellant tank outlet.

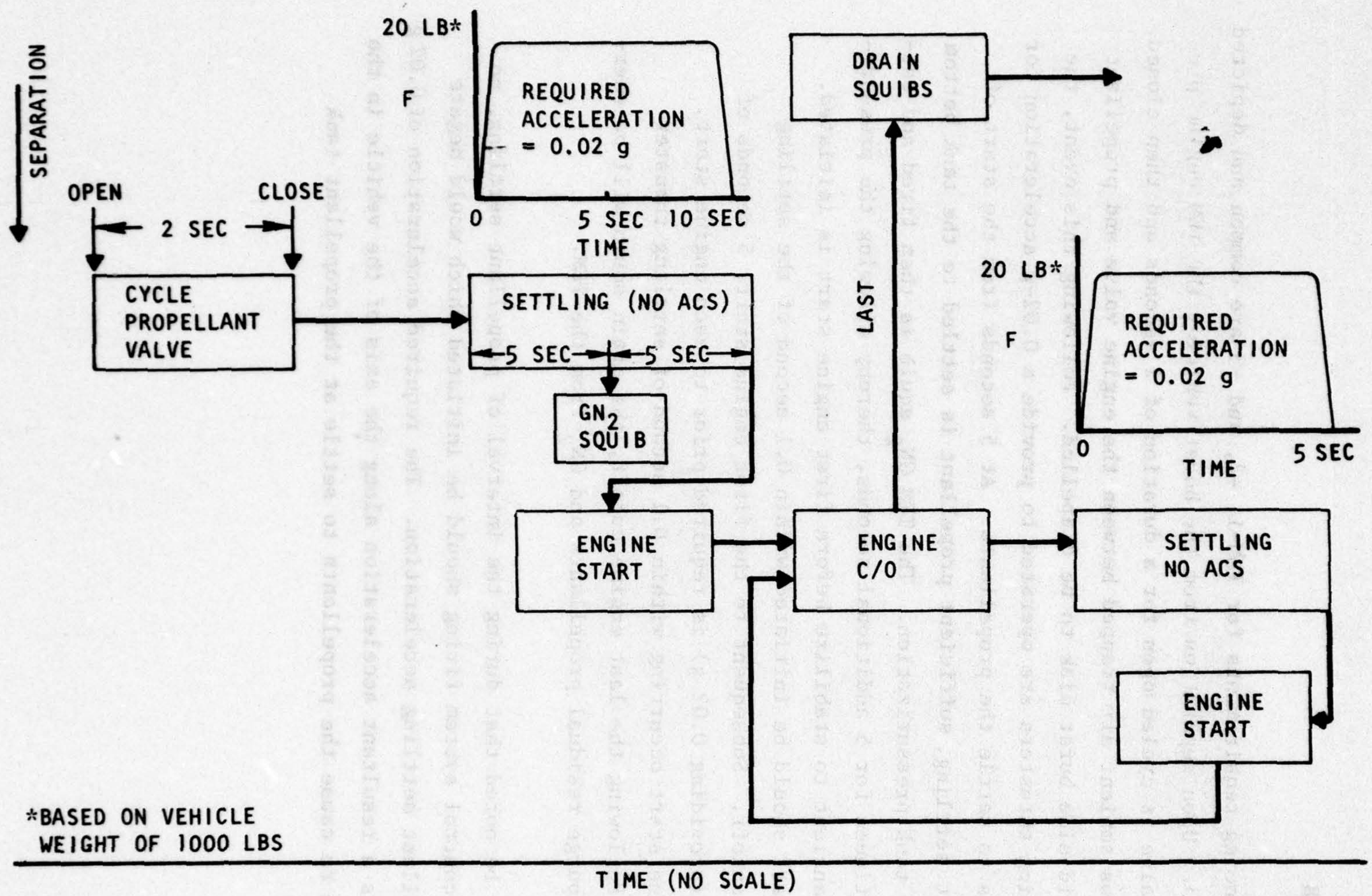


Figure 13. TEM Sequencing

LOW-THRUST TARGET ENGINE (ROCKETDYNE RS-1401)

The RS-14 is a high-performance, bipropellant, pressure-fed rocket engine that was developed to provide maneuvering thrust for a space vehicle. It uses nitrogen tetroxide and monomethylhydrazine propellants to produce 315 pounds nominal vacuum thrust. As delivered to the Air Force, the engine consists of a multi-element, unlike-doublet pattern injector with boundary layer cooling; a beryllium combination heat sink/internal-regenerative thrust chamber; a thrust mount and gimbal assembly; and a torque motor-actuated, mechanically linked bipropellant valve. Nozzle area ratio is 30:1, overall length is 16.1 inches, and weight is 19.41 pounds.

Design efforts to determine the RS-1401 hardware mounting to the stage structure involved a thrust bracket that attached to the valve/thruster body and provided a mount to the stage structure. The thrust mount adapter was designed so that shimming or grinding could be used for alignment of the engine thrust vector. The mounting adapter utilized an interface to the structure similar to that used to mount the LR101-NA-7 thrust chamber (modified Atlas vernier engine discussed elsewhere).

Modifications to the RS-14 engine consisted of removal of the gimbal ring assembly and the substitution of three Z-shaped mounting brackets (TEP1003) bolted to existing threaded holes on the injector flange (Fig. 14). Three sets of mounting brackets were fabricated from a single piece of 4340 steel bar to minimize overall tolerance variation. This material has a heat-treat range of 125,000 to 140,000 psi (Fig. 15).

Thrust alignment was verified by using a spherically designed alignment tool fabricated from aluminum. The two-piece tool consisted of a sliding plate and a shaft with a small sperical flange on the end (Fig. 16). The spherical flange was inserted to fit into the thrust chamber throat

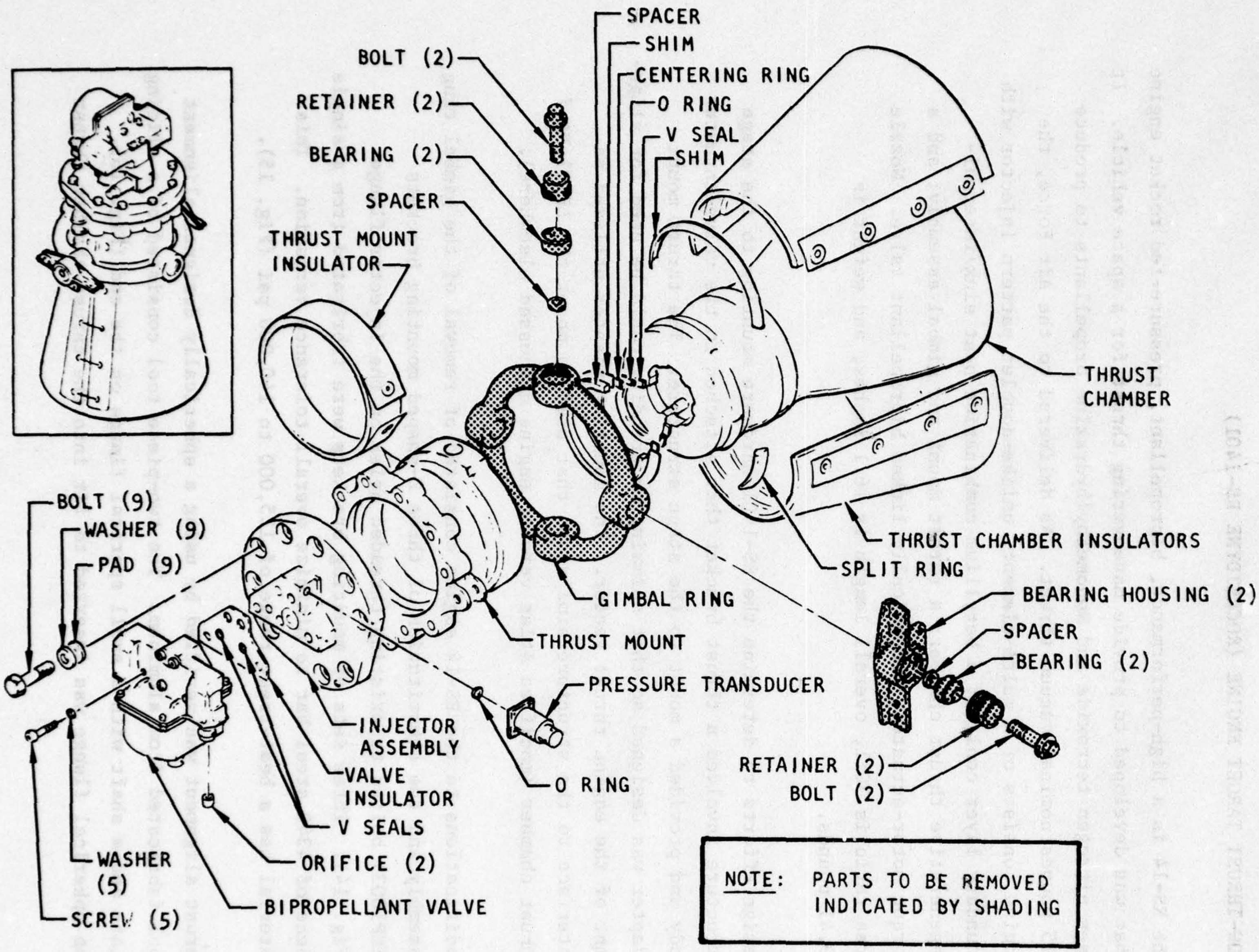
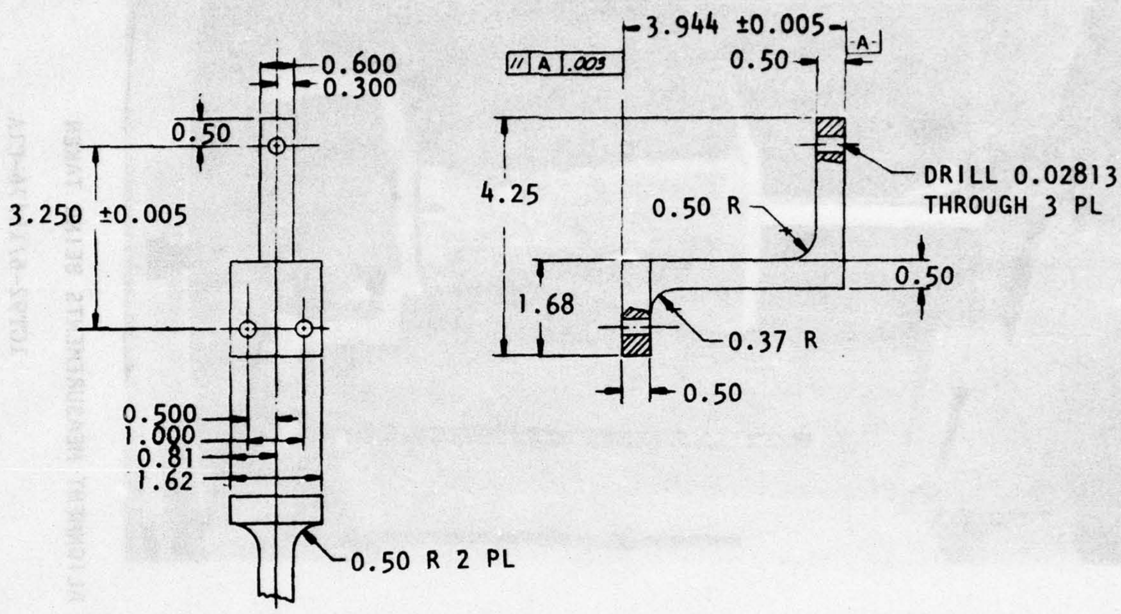
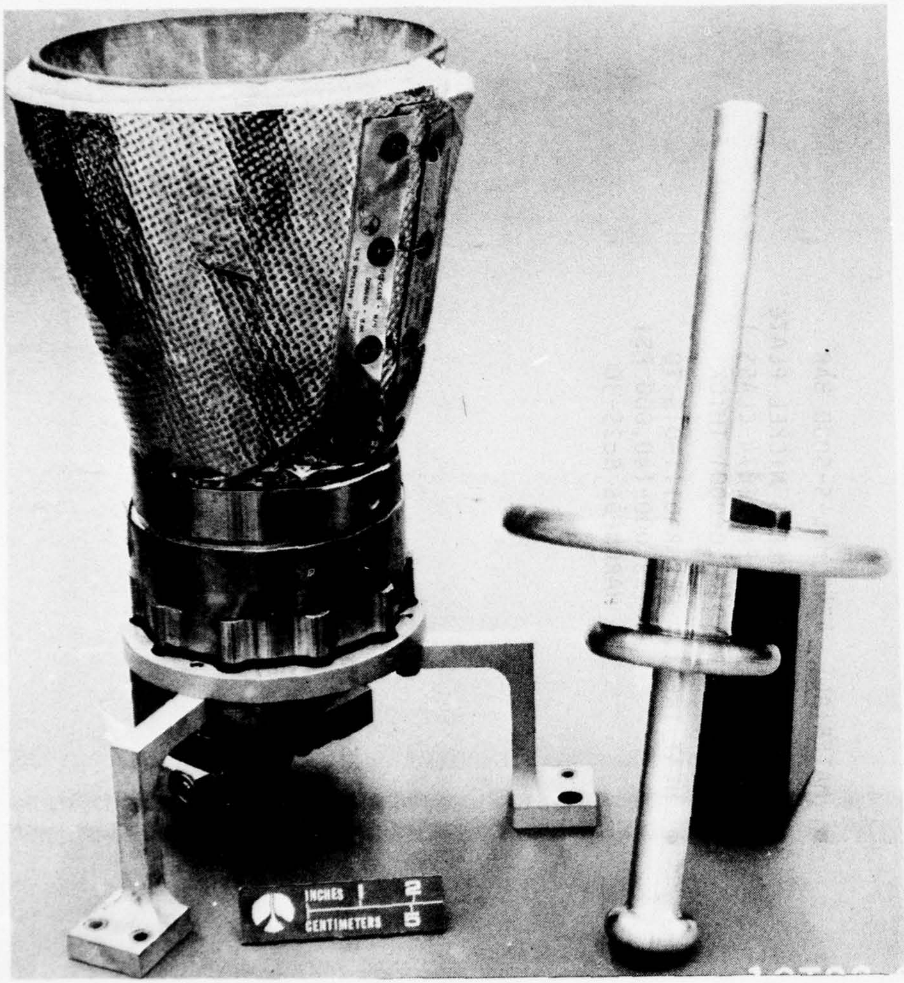


Figure 14. RS1401 Modifications



- MATERIAL: 4340 MIL-S-5000 BAR
- FINISH: ELECTROLESS NICKEL PLATE
  PER MIL-N-26074 CLASS I
  0.0010 ±0.0001 THICK
- HEAT TREAT: PER RA0111-015 TO
  125,000-140,000 PSI
  HARDNESS Rc25-30

Figure 15. RS-14 Mounting Bracket (3 Required)



A. MODIFIED RS-14 WITH ALIGNMENT TOOL

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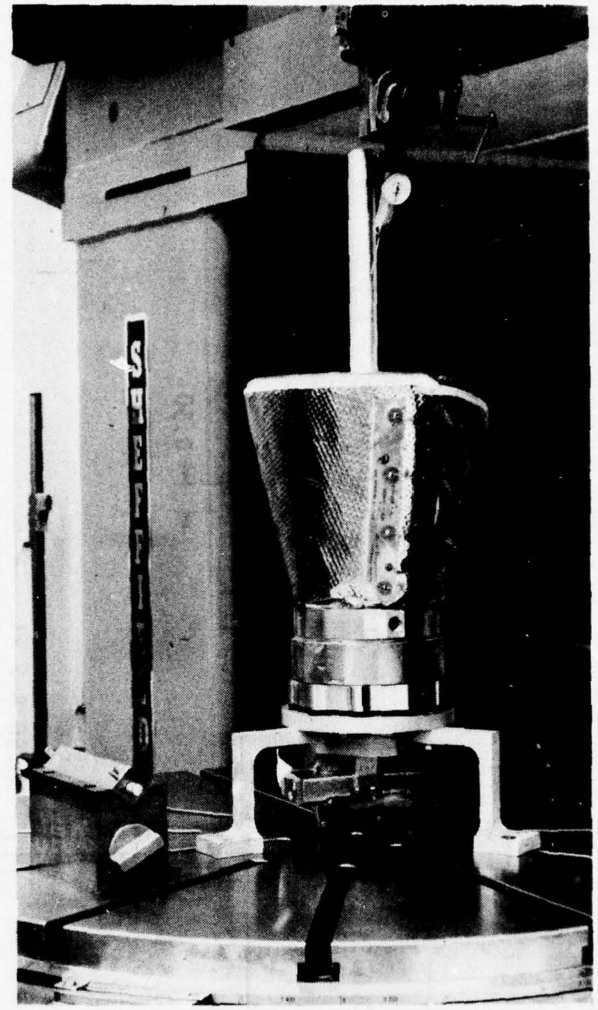


B. ALIGNMENT MEASUREMENTS BEING TAKEN

1GT92-6/15/76-C1A

Figure 16. Target Engine System Alignment

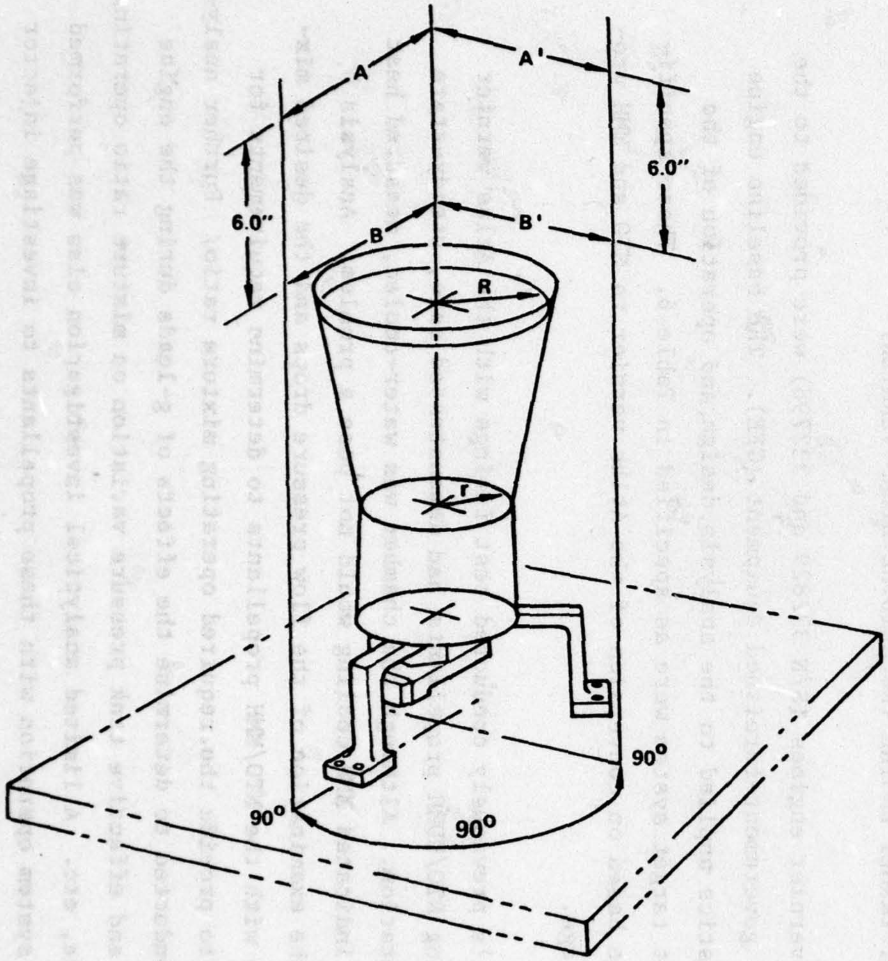
diameter and the sliding plate adjusted to fit into the chamber exit diameter. The shaft was then measured to determine angularity of the thrust chamber nozzle (Fig. 17).

Both the spherical shaft end and the sliding plate with a spherical outer surface are self-centering. The sliding plate can be reversed to fit the nozzle exit diameter of the vernier engine nozzle. Because of the close fit between the sliding plate and the shaft, the centerline of the nozzle can be determined with extreme accuracy. In all cases, the inclination of the nozzle centerline was well within the 0.1 degree allowed.

HIGH-THRUST TARGET ENGINE (ROCKETDYNE ATLAS VERNIER)

Two Atlas vernier engines (S/N 332829 and 332798) were provided to the program as government-furnished equipment (GFE). The baseline engine characteristics applied to the analysis,design,and operation of the high-thrust target system were as specified in Table 6. These specifications are based on conversion of the Atlas vernier to NTO and MMH propellant usage.

Rocketdyne's previously conducted test firings with the Atlas vernier engine using NTO/UDMH propellants had demonstrated safe, steady-state engine operation. Although the chamber was water-cooled, measured heat flux data indicated MMH cooling would not pose a problem. Analysis included the examination of the flow pressure drops and the desired mixture ratio with the NTO/MMH propellants to determine requirements for orificing to provide the required operating mixture ratio. Further analysis was conducted to determine the effects of g-loads during the engine operation and effective tank pressure variation on mixture ratio operating performance, etc. A limited analytical investigation also was performed on engine system operation with these propellants to investiage injector characteristics, injection momentum, combustion stability, and chamber



REQUIREMENT

0.1° (6')

MEASUREMENT

0.06° (3.6')

$A-B = 0.0045''$

$A'-B' = 0.0040''$

$$\text{RESULTANT} = \sqrt{\overline{A-B}^2 + \overline{A'-B'}^2}$$

$= 0.0060207''$

OR

0.001003 IN/IN

$\text{TAN } 0.1^{\circ} = 0.0017$

RESULTING ANGULAR ALIGNMENT IS 0.0602°

Figure 17. TES Engine Alignment

TABLE 6. LR101-NA-7 (ATLAS VERNIER) ENGINE CHARACTERISTICS

Propellants		
Oxidizer	Liquid Oxygen: Convert to nitrogen tetroxide (MON-1), NTO; MIL-P-27404	
Fuel	RP-1: Convert to monomethylhydrazine, MMH; MIL-P-25508	
Envelope		
Overall Length, inches	16	
Maximum Diameter, inches	5	
Weight, pounds	24	
Performance	**Original**	**Approximate Conversion**
Chamber Pressure, psia	358	358
Thrust (vacuum), lbf	1150	1150
Specific Impulse (vacuum) seconds	230	230
Mixture Ratio (o/f)	1.8	1.6
Oxidizer and Fuel Inlet Pressure, psia	630	630
Chamber Cooling		
Regenerative with fuel		

cooling limits. This effort was primarily to determine that, should off-nominal (i.e., mixture ratio or tank pressure) operation occur during the flight, no deterimental operation would result. These efforts were limited to those necessary to ensure safe operation within the normal system parameter variations which might occur. The limits specified are discussed in Task II.

The effort in this task was principally directed toward: (1) identifying the hardware modifications required for the propellant conversion (i.e., software changes), (2) identifying the modification necessary for the new installation, and (3) providing the hardware design for the necessary hardware modification. The modifications for the engine are shown in Table 7. In addition, stress analysis of the engine system was conducted to ensure that the engine would operate under the launch and operating environment vibration and g-load effects.

TABLE 7. LR101-NA-7 (ATLAS VERNIER) ENGINE HARDWARE MODIFICATION

Hardware/Part	Modification
Hypergolic Cartridge Container	Remove and install flanged connection at fuel manifold to be used as fuel inlet port
Gimbal Shafts	Remove gimbal shafts
Dome Bolts	Change length of bolts
Thrust Mount	Thrust mounts adapter (new); attaches to LOX dome

The Atlas vernier engine assembly (LR101-NA-7) consists of a bipropellant valve, a thrust chamber body, an oxidizer dome, and a propellant injector. The bipropellant valve is mounted on the gimbal body. The dome and injector are brazed together as a single unit and are bolted to the thrust chamber body. The thrust chamber, which is fabricated from 4130 steel, is regeneratively cooled by fuel flowing between the passages defined by a spiral copper-wire helix that has been silver soldered to the inner and outer 4130 steel chamber shells. Fuel flows through a hypergol container, enters the chamber inlet manifold located at the nozzle exit, and continues between the chamber walls before being discharged into the injector housing.

Initially, the vernier engine assembly was modified by disassembling the thrust chamber assembly from the gimbal body. The hypergolic cartridge container was removed from the chamber by cutting the tube at the exit end inlet manifold; the gimbal propellant passages and sector gear ring spline also were cut from the chamber body (Fig. 18).

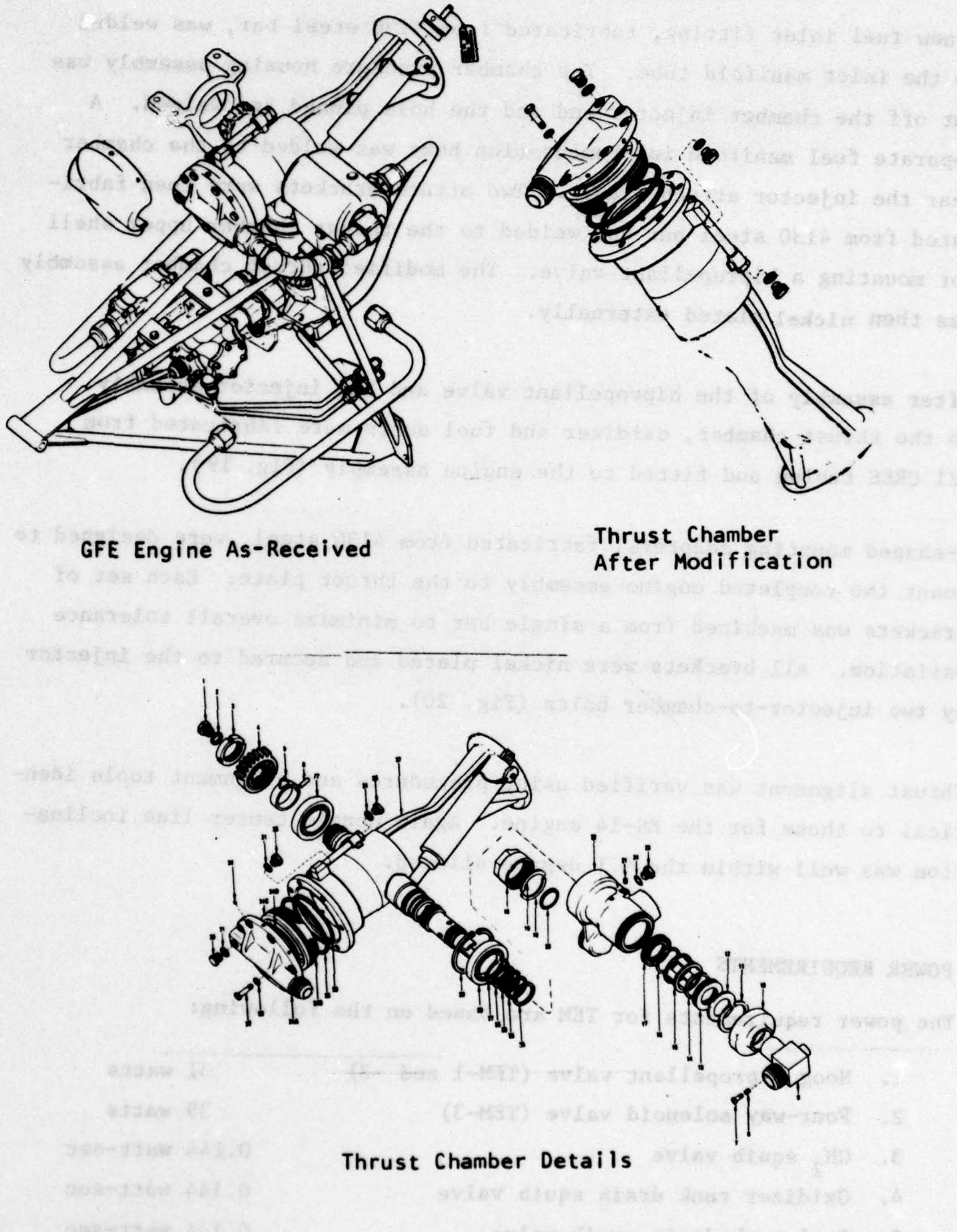


Figure 18. Modifications to LR101-NA-7 Engine

A new fuel inlet fitting, fabricated from 4130 steel bar, was welded to the inlet manifold tube. The chamber pressure housing assembly was cut off the chamber injector end and the hole pinned and welded. A separate fuel manifold instrumentation boss was welded to the chamber near the injector attach flange. Two attach brackets were then fabricated from 4130 steel bar and welded to the thrust chamber upper shell for mounting a bipropellant valve. The modified thrust chamber assembly was then nickel plated externally.

After assembly of the bipropellant valve and the injector assembly to the thrust chamber, oxidizer and fuel ducts were fabricated from 321 CRES tubing and fitted to the engine assembly (Fig. 19).

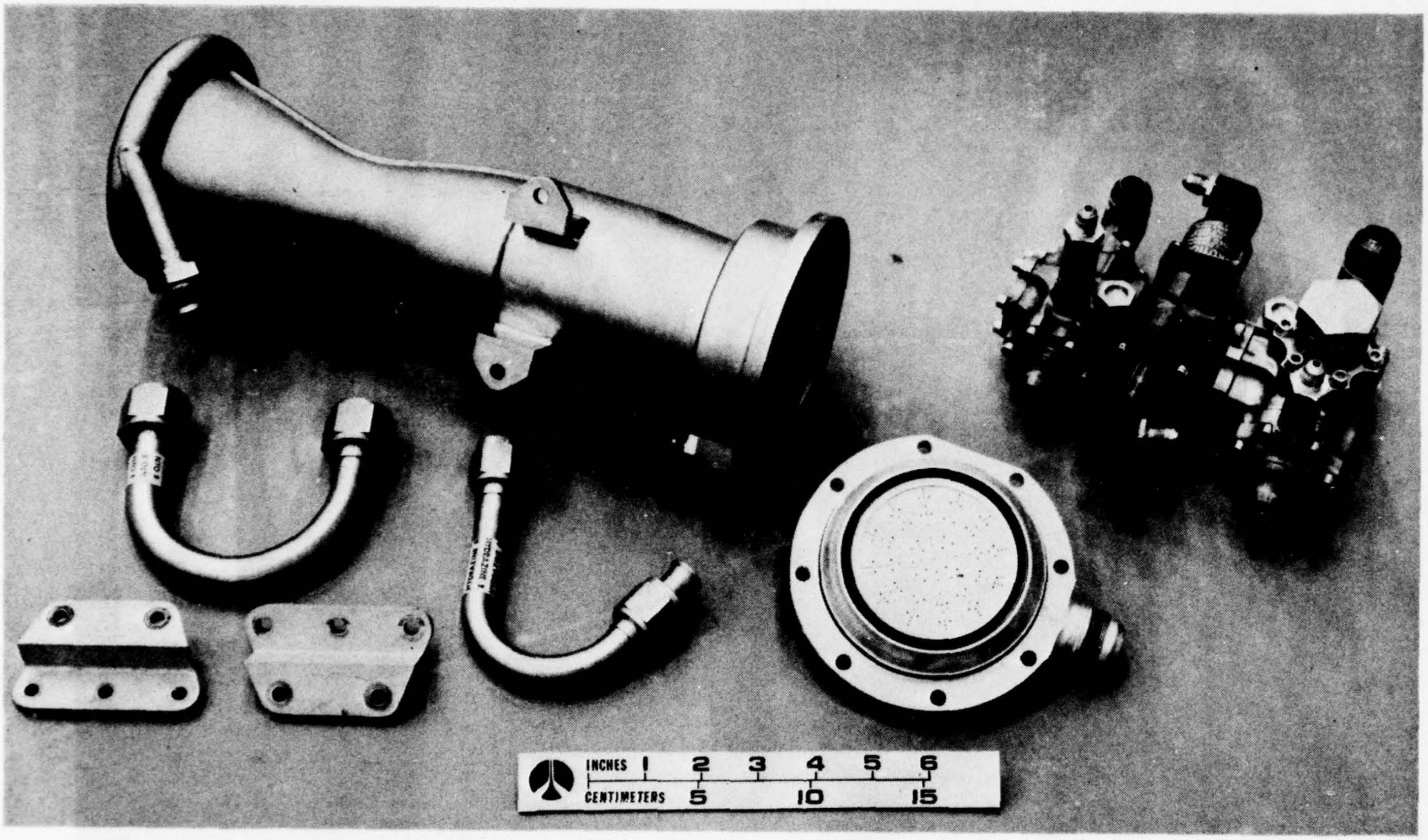
Z-shaped mounting adapters, fabricated from 4130 steel, were designed to mount the completed engine assembly to the thrust plate. Each set of brackets was machined from a single bar to minimize overall tolerance variation. All brackets were nickel plated and secured to the injector by two injector-to-chamber bolts (Fig. 20).

Thrust alignment was verified using procedures and alignment tools identical to those for the RS-14 engine. Again nozzle center line inclination was well within the 0.1 degree allowed.

POWER REQUIREMENTS

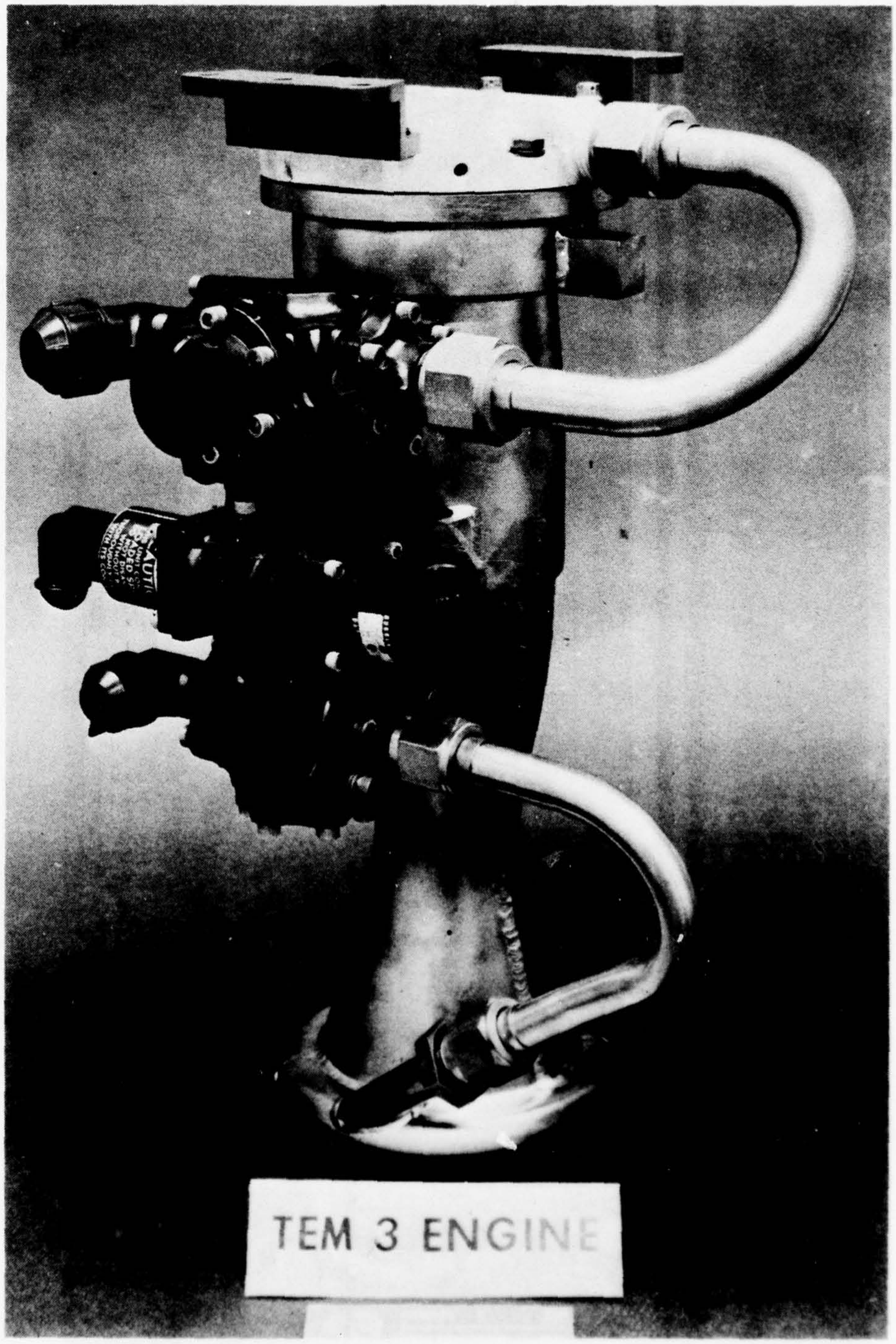
The power requirements for TEM are based on the following:

1.	Moog bipropellant valve (TEM-1 and -2)	31 watts
2.	Four-way solenoid valve (TEM-3)	39 watts
3.	GN_2 squib valve	0.144 watt-sec
4.	Oxidizer tank drain squib valve	0.144 watt-sec
5.	Fuel tank drain squib valve	0.144 watt-sec



1GT25-11/26/75-C1C

Figure 19. Modified Atlas Vernier Engine Components



1BM22-11/12/75-C1B*

Figure 20. TES Complete Engine

6. Pressure transducers (five) 1.6 watts

7. Temperature transducers (three) 3.4 watts

TEM-1 and -3 power applications are depicted in Fig. 21 and 22, respectively. The power supply is 28 ±4 Vdc.

ROCKET EXHAUST PLUME HEATING

When the target engines are fired at high altitudes, i.e., near-vacuum ambient conditions, the rocket exhaust plumes will expand radially to very large diameters. The rocket exhaust gas in the jet boundaries can impinge on the target module base and skin and cause heating to occur. Accordingly, analyses of the near-field exhaust plume effects from the RS-14 and vernier rocket engines using NTO/MMH propellants were conducted. Figure 23 illustrates the flow conditions that exist in the plume of the RS-14 engine. The nozzle expands the hot gas to an area ratio of 30:1. This nozzle exit plane is shown in the lower left corner of the figure. The plot shows the plume expanding immediately upon leaving the nozzle, resulting in low static temperatures and high Mach numbers near the plume boundary. The expansion of the nozzle boundary layer continues beyond the primary gas jet boundary but is not shown in this figure.

The vernier engine will expand the gas in the nozzle to an area ratio near 5:1 and, in a vacuum, the jet exiting from the nozzle will plume out upstream of the nozzle exit plane (Fig. 24). Thus, the aft closure for the rocket engine assembly will interfere with the free jet expansion, and jet impingement will occur on the surfaces.

Base heating will result from the jet plumes because of exhaust gas radiation and convention effects, even though the plume does not impinge directly on the base. The boundary layer gas would expand upstream in a free jet. With the restriction of the base plate, scouring of the base will occur.

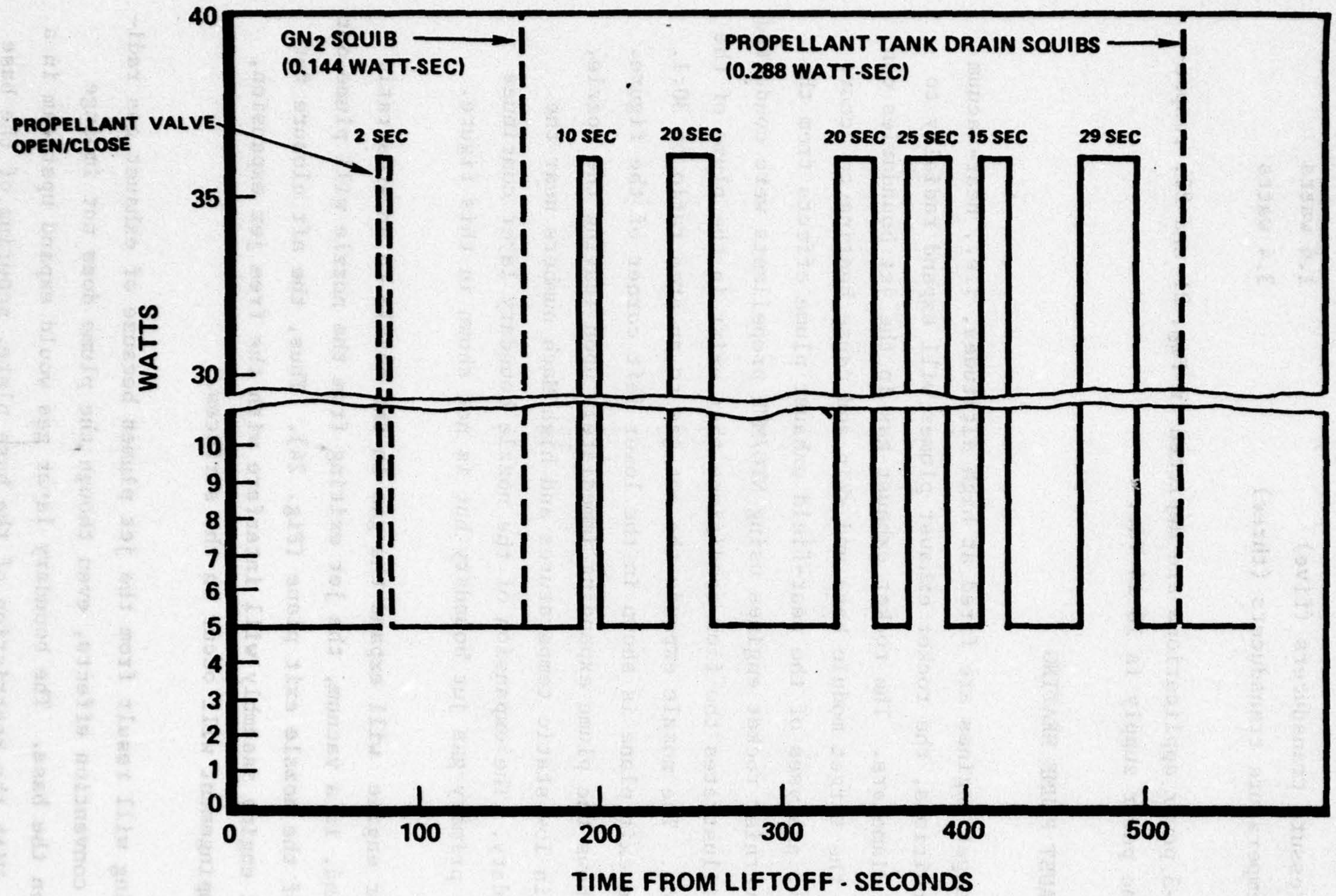


Figure 21. TEM-1 Power Requirements

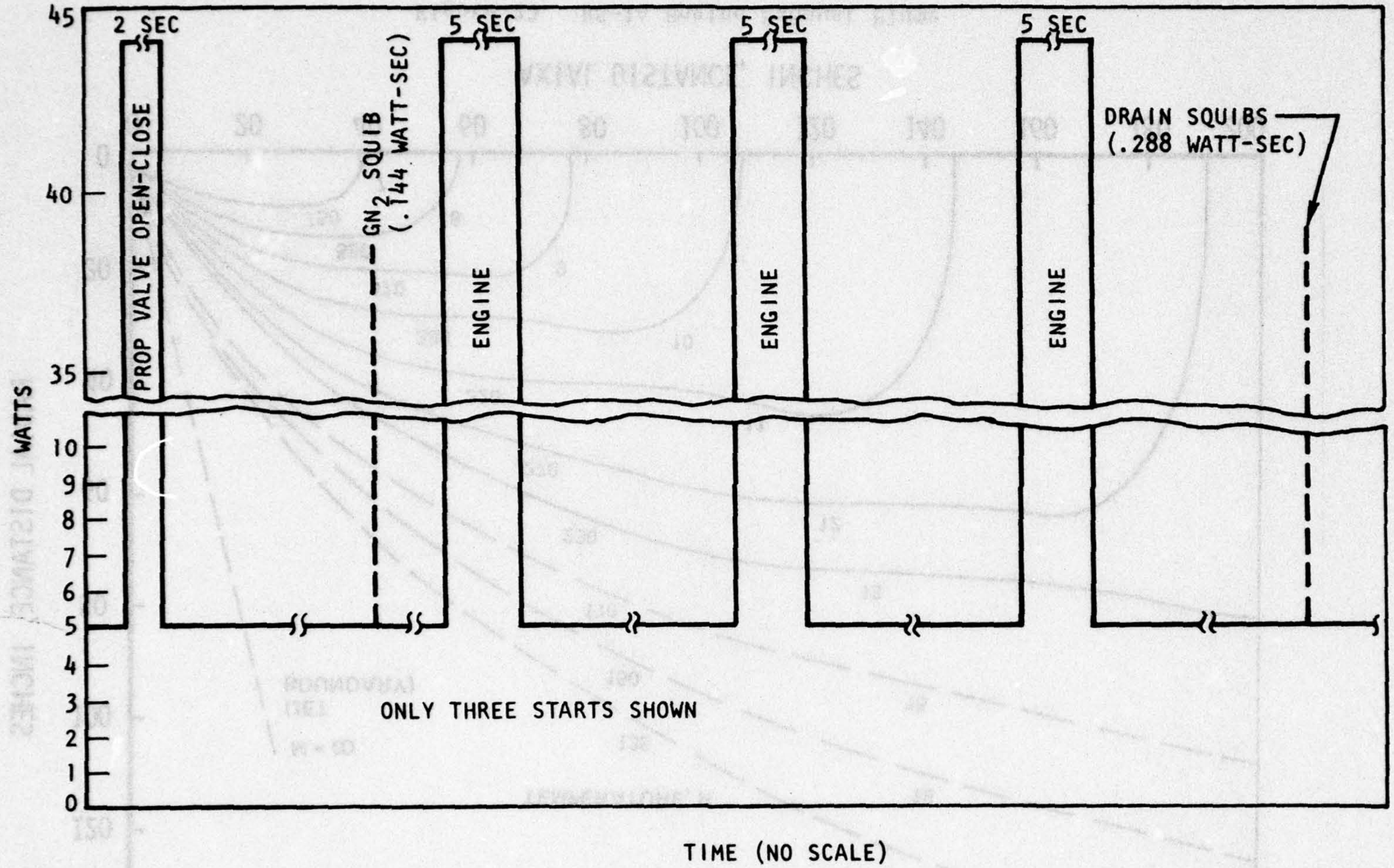


Figure 22. TEM-3 Power Requirements

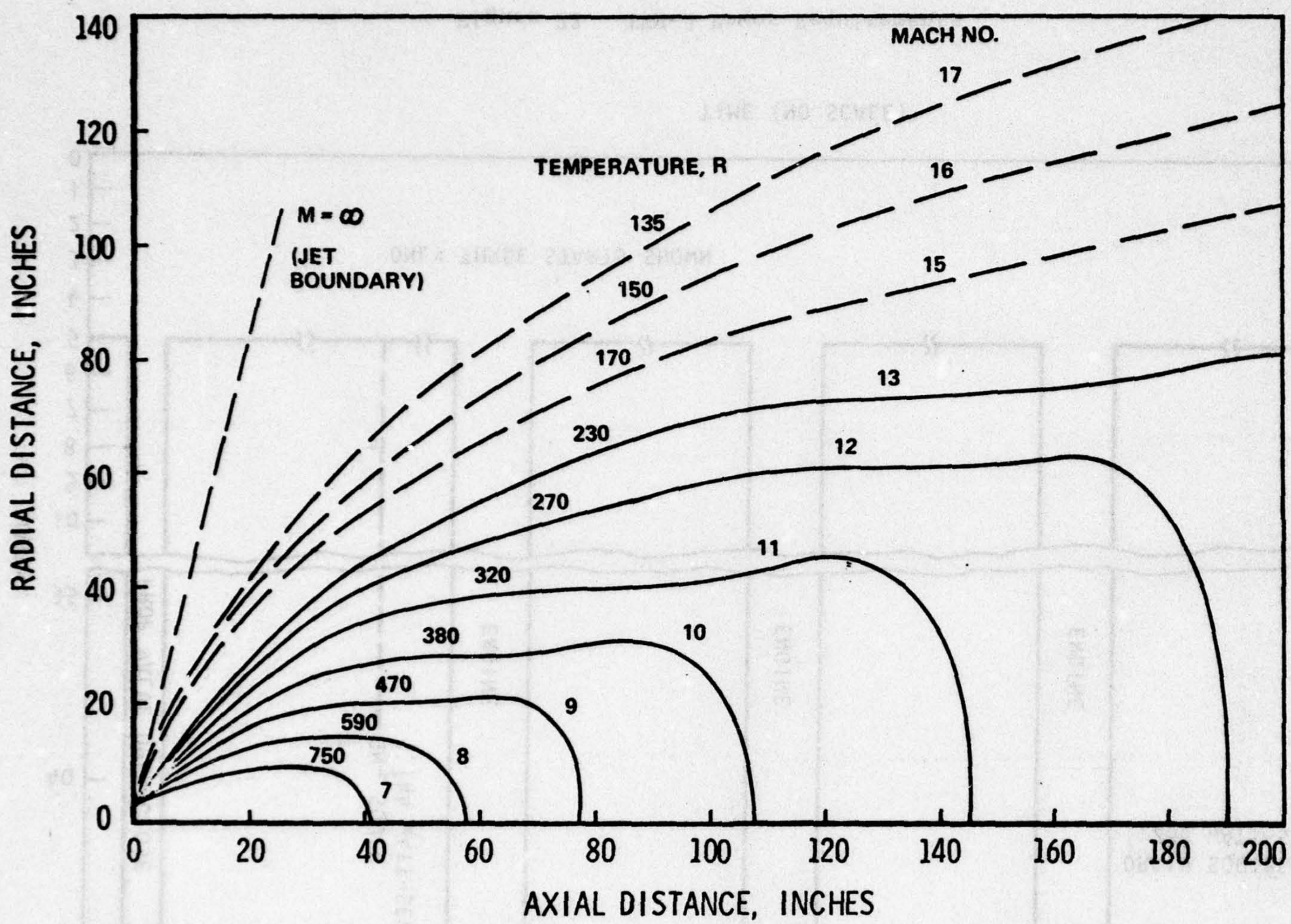


Figure 23. RS-14 Engine Exhaust Plume

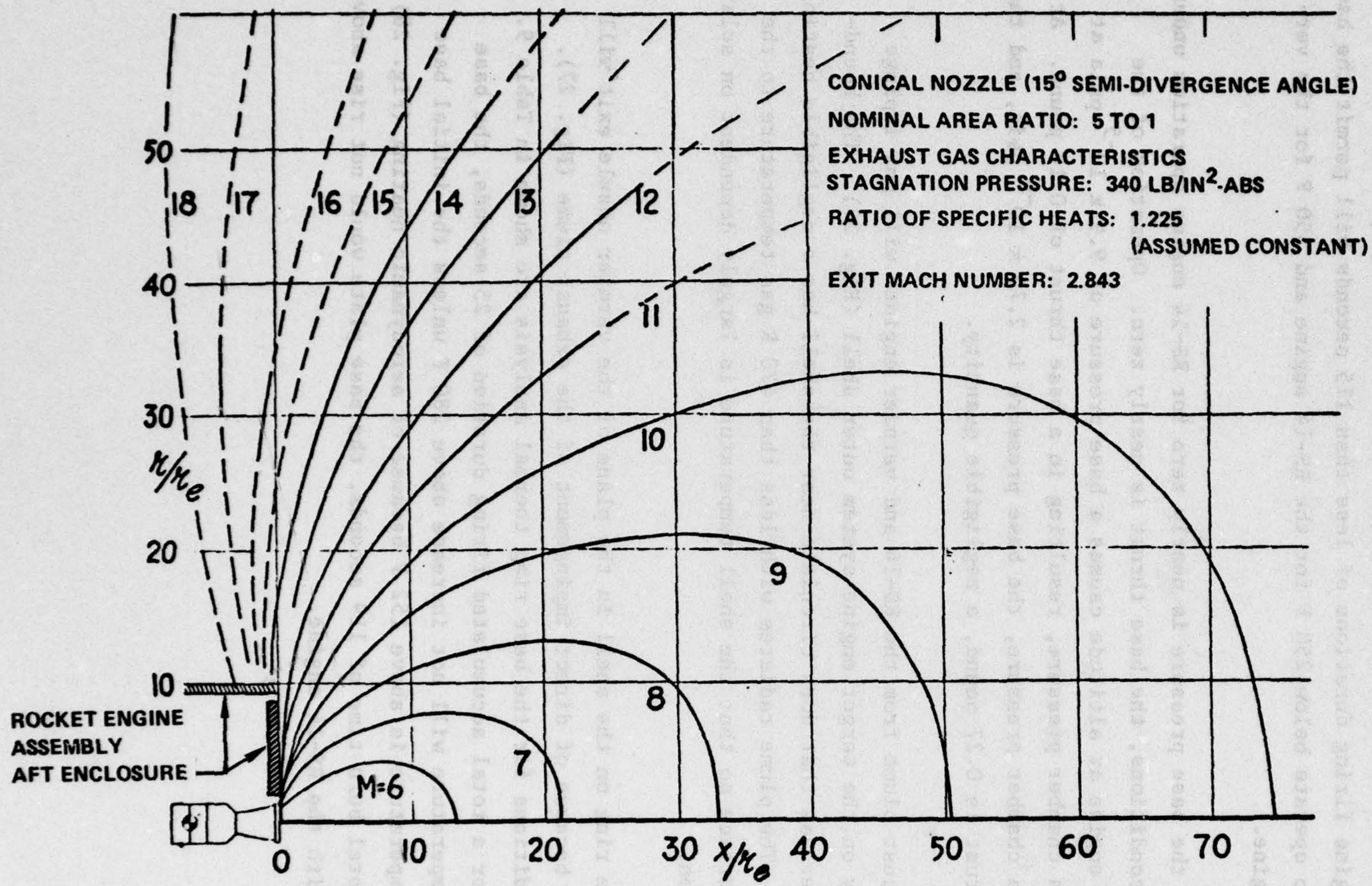


Figure 24. Theoretical Mach Numbers for the Vernier Rocket Exhaust Expansion Into a Vacuum

Figure 25 is a plot of the aft cover plate wall temperature versus heat flux for varying engine firing durations and engine types. The plot shows that engine firing durations of less than 115 seconds will permit the base plate to operate below 250 F for the RS-14 engine and 350 F for the vernier engine.

Because the base pressure is nearly zero for RS-14 engine operation under vacuum conditions, the base thrust is nearly zero. Operation of the vernier engine at altitude causes a base pressure of 9.9×10^{-5} psia at 125 psia chamber pressure, resulting in a base thrust of 0.10 pound. At 340 psia chamber pressure, the base pressure is 2.70×10^{-4} psia, and the base thrust is 0.27 pound, a negligible quantity.

The exhaust plume from the RS-14 and vernier engines will not impinge directly on the target engine system outer shell (Fig. 26). The boundary layer gas that does circulate near the shell has a negligible heating effect. The plume radiates with less than 470 R gas temperature to the shell surface so that the shell temperature is largely dependent on solar radiation.

The base ring on the shell in the plane of the vernier nozzle exit will heat up because of direct impingement of the exhaust plume (Fig. 27). The conditions for the base ring thermal analysis are shown in Table 9. Thus, for a total accumulated firing duration of 25 seconds, the base ring temperature will not increase above 280 F unless the initial base ring temperature is above 152 F because of aerodynamic heating (Fig. 28). For a total burn time of 119 seconds, the base plate would not rise above 300 F with the RS-14 engine.

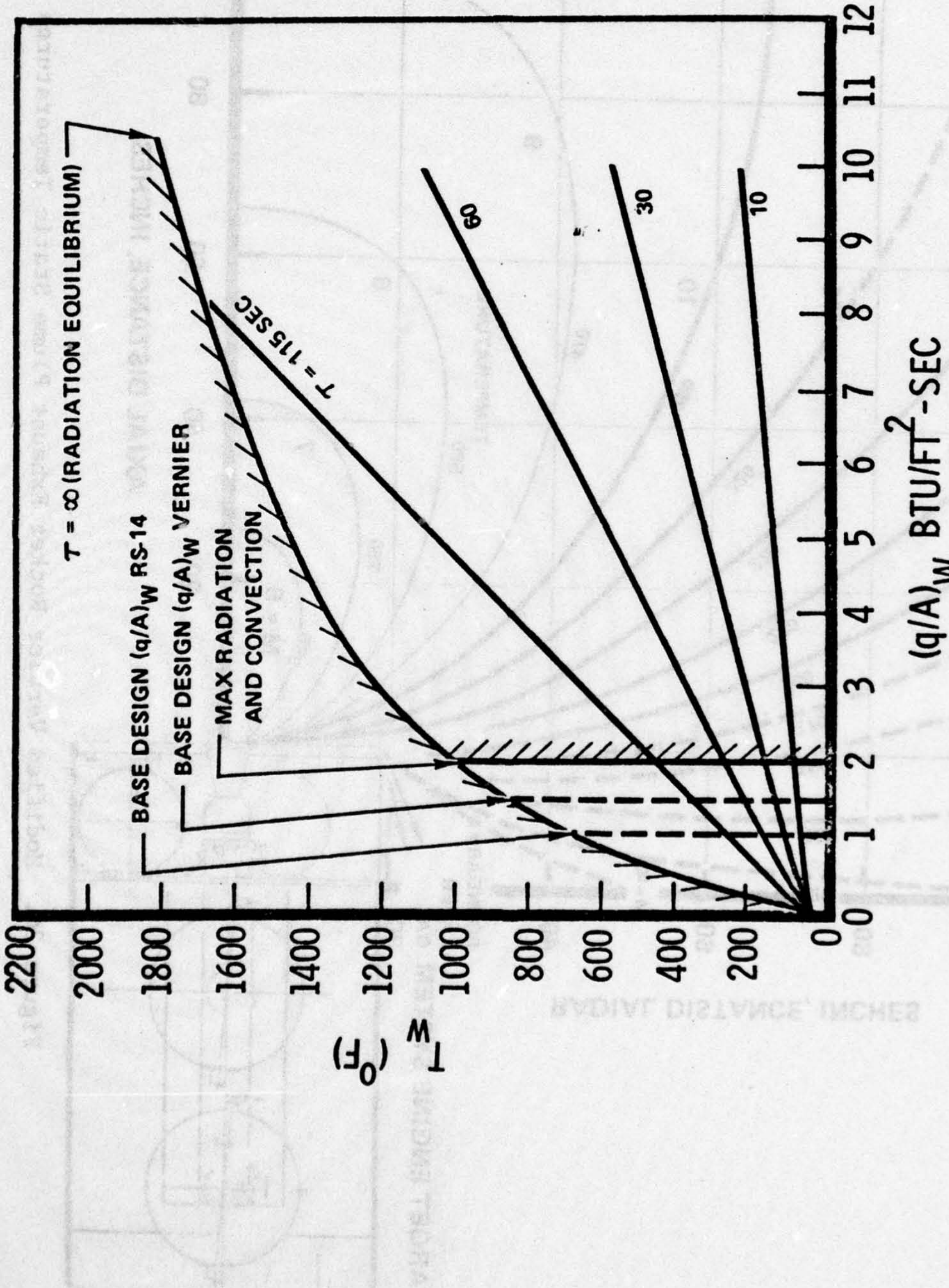


Figure 25. Wall Temperature Versus Heat Flux

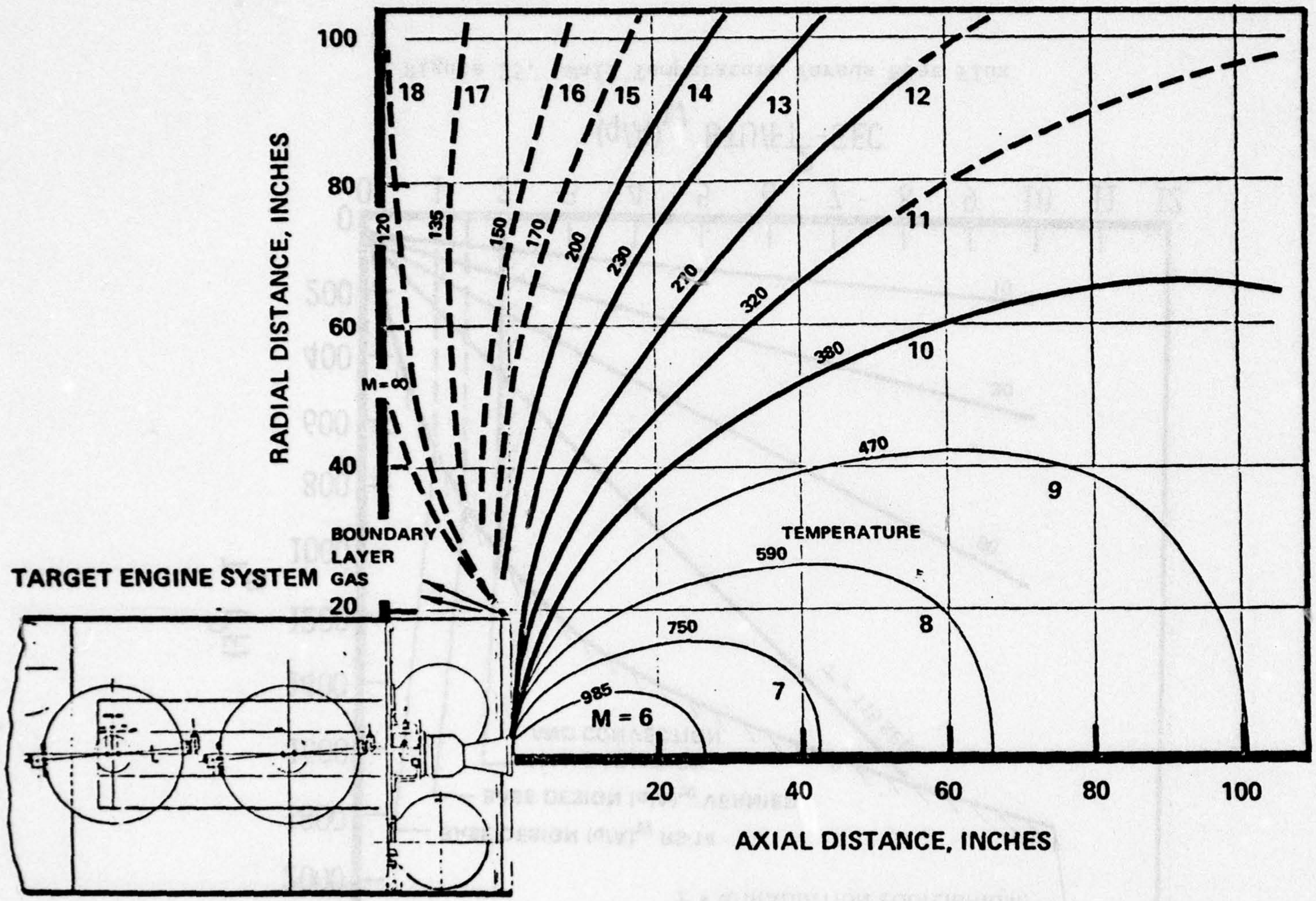


Figure 26. Modified Vernier Rocket Exhaust Plume Static Temperatures

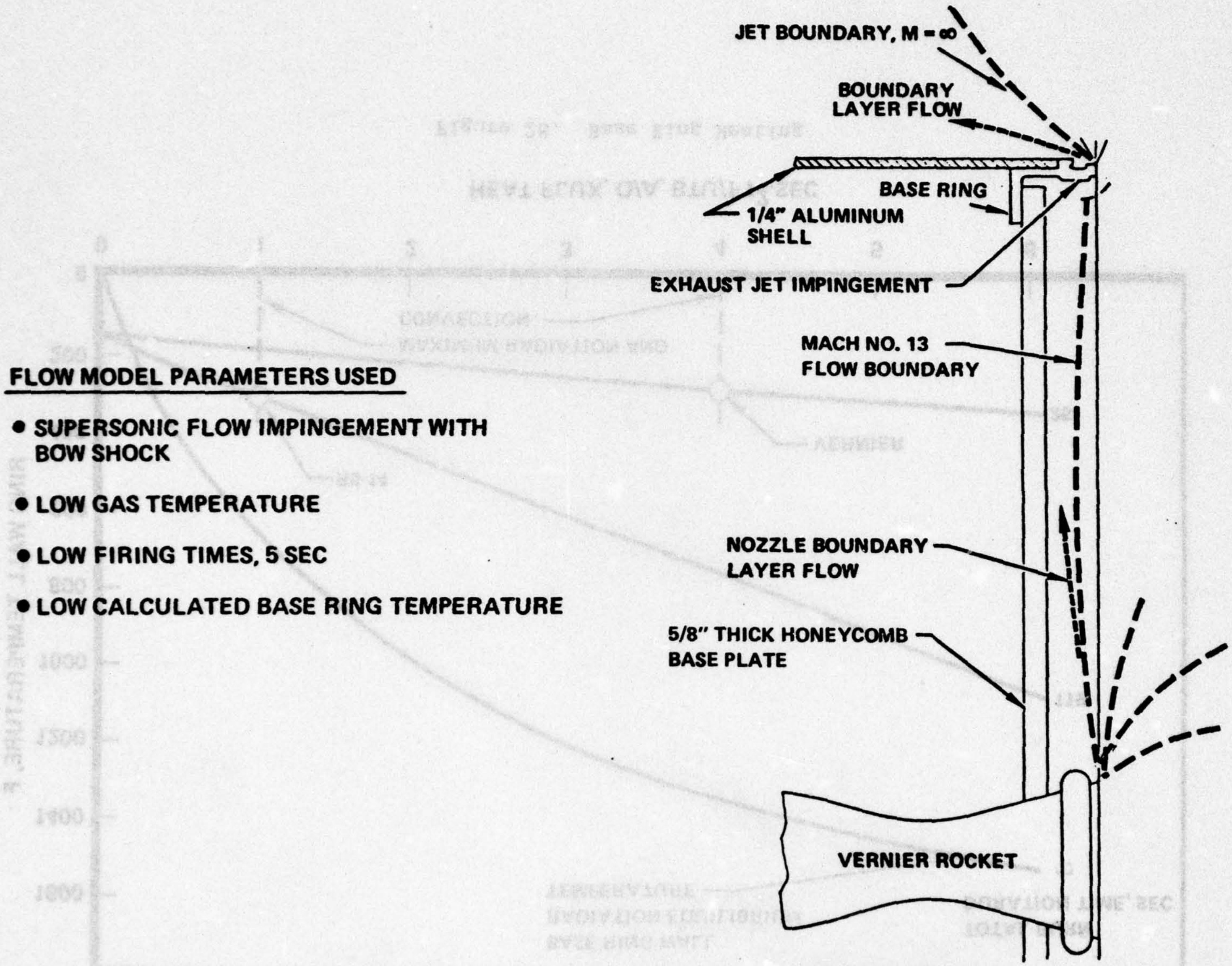


Figure 27. Base Ring Heating-Vernier Rocket Exhaust

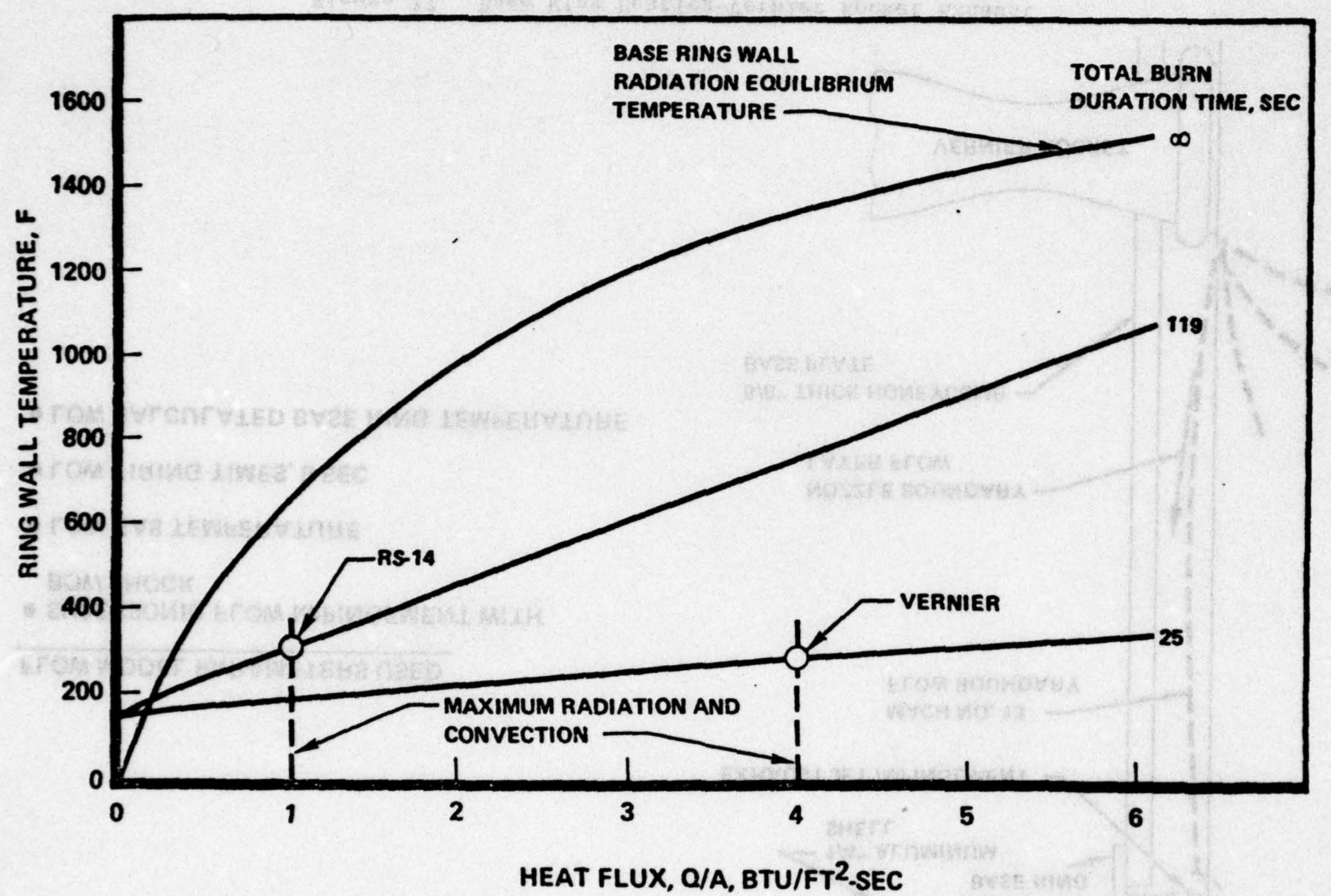


Figure 28. Base Ring Heating

TABLE 8. BASE RING THERMAL ANALYSIS WITH VERNIER EXHAUST

• Impingement Mach Number	13.0
• Impingement Total Temperature, R	5530
• Impingement Static Temperature, R	215
• Impingement Recovery Temperature, R	3030
• Impingement a/A, Btu/ft^2-sec	2.9
• Convection and Radiation Heat Flux, Btu/ft^2-sec	4.0
• Total Duration of Firings, seconds	25
• Base Ring Temperature Rise, F	128
• Base Ring Initial Temperature (aerodynamic heating), F	152
• Maximum Ring Temperature, F	280

Vernier Rocket Wall Temperatures With NTO/MMH

Results of a heat transfer analysis of the vernier engine using NTO/MMH propellants indicated a peak inside wall temperature of 1120 F, which was within the structural capability of the gas-side wall (Fig. 29). This was based on a throat coolant (MMH) velocity of 54 ft/sec and a throat heat flux of 6.3 $Btu/in.^2$-sec. The margin of safety to throat burnout heat flux was calculated at 160 percent with MMH coolant leaving the chamber at 350 F, approximately 90 F below the boiling point of MMH. Subsequent hot-fire test data showed that the MMH temperature leaving the jacket was 200 to 220 F, and that a significant margin of safety existed regarding inner-wall burnthrough.

Thermal Characteristics of RS-14 Chamber

The RS-14 is a fully qualified rocket engine currently used in the Minuteman III Post-Boost Propulsion System. The engine employs a fuel (MMH) film-cooled beryllium thrust chamber to deliver 315 pounds of thrust at a chamber pressure of 125 psia using NTO/MMH propellants (MR = 1.6). Operation of the thrust chamber, which is of single-piece construction, is essentially in a heat sink cooling mode as shown in Fig. 30. The maximum allowable accumulated burn duration is approximately 260 seconds,

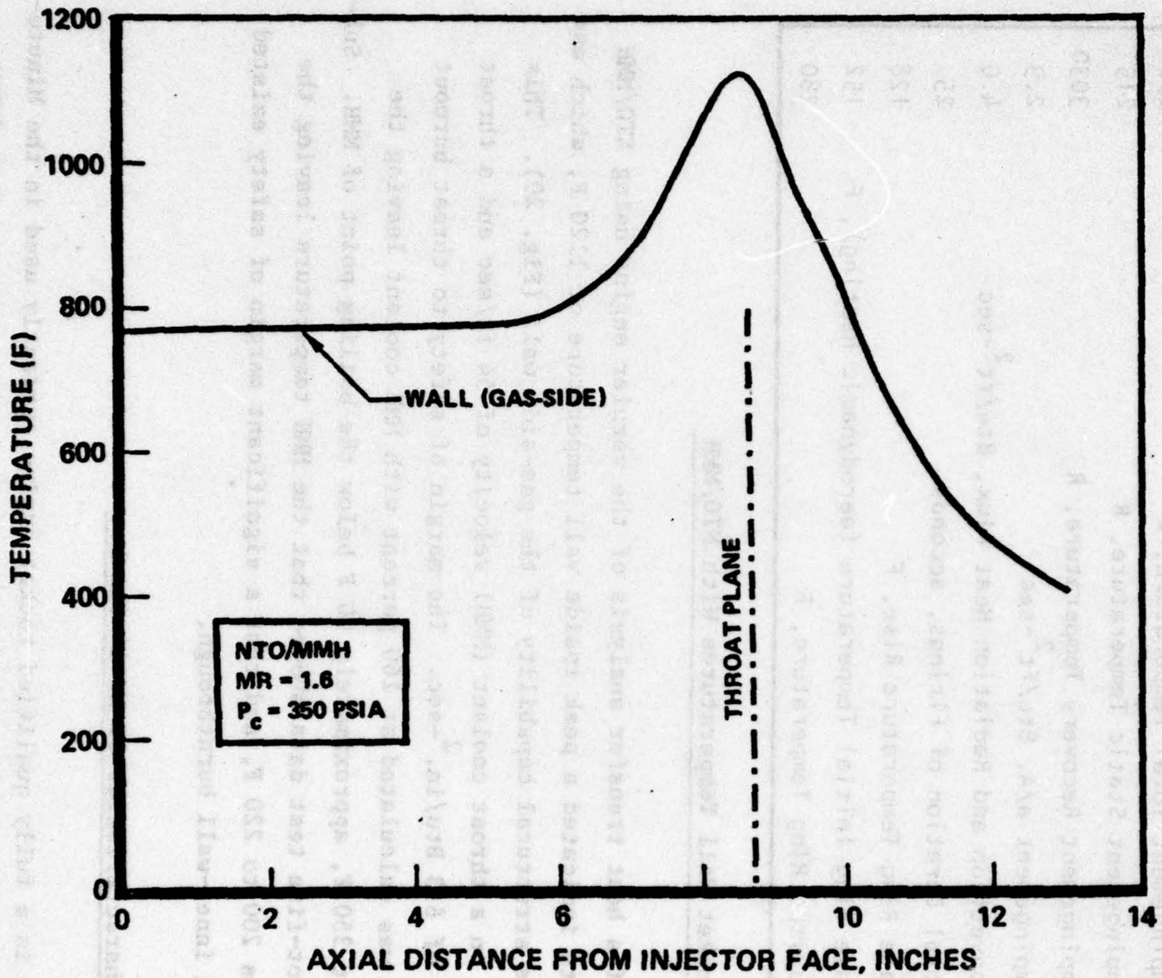


Figure 29. Vernier Rocket Chamber Inner Wall Temperature

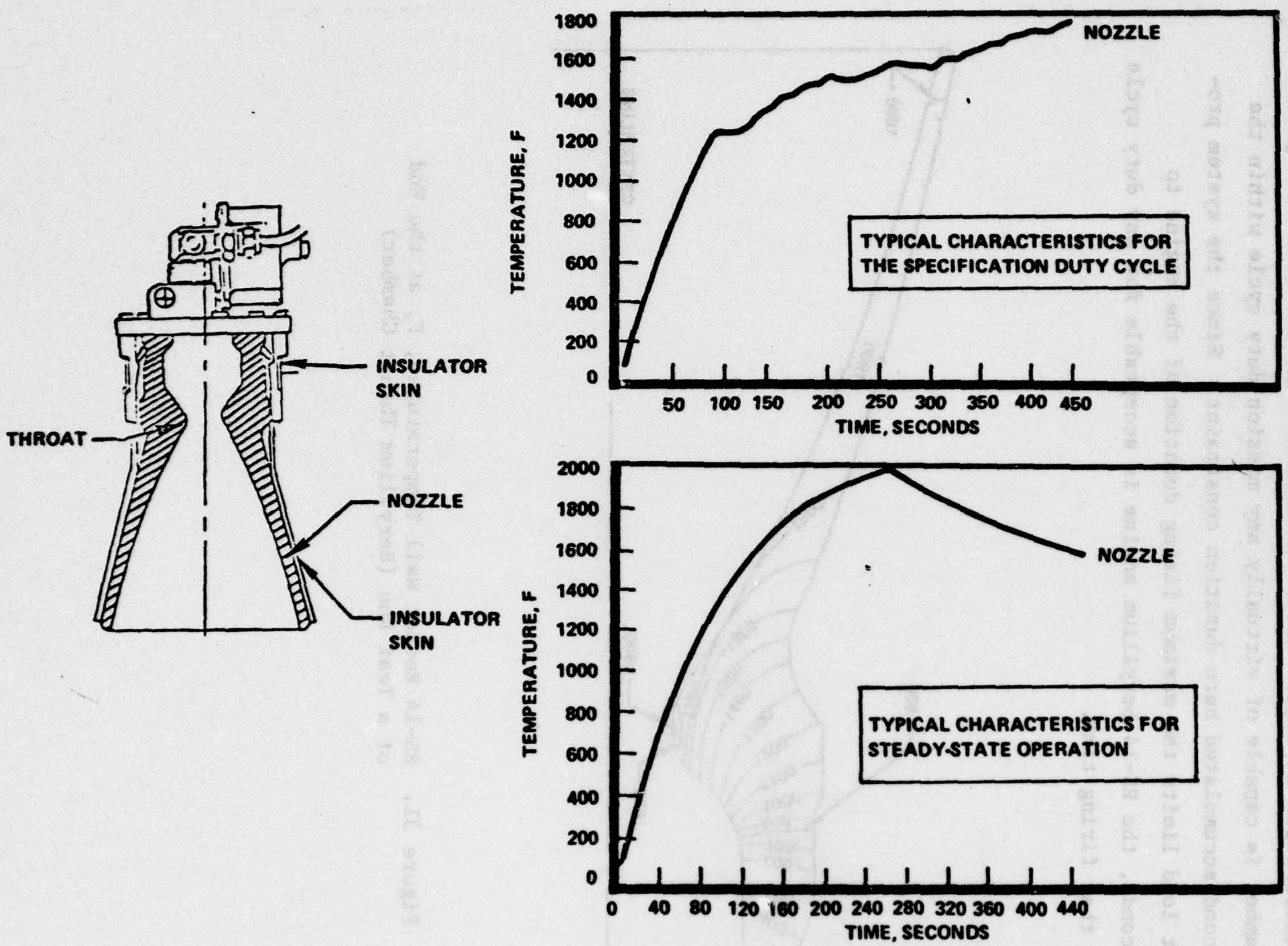


Figure 30. RS-14 Thrust Chamber Nozzle Wall Temperature vs Time

based on a maximum chamber wall temperature of 2000 F. Chamber temperature distribution at cutoff after 260 seconds burn is shown in Fig. 31. The chamber is capable of virtually any mission duty cycle within the 260-second accumulated burn duration constraint. Since the system propellant load limits the maximum firing duration of the engine to 114 seconds, the RS-14 beryllium engine is acceptable for any duty cycle within that firing time.

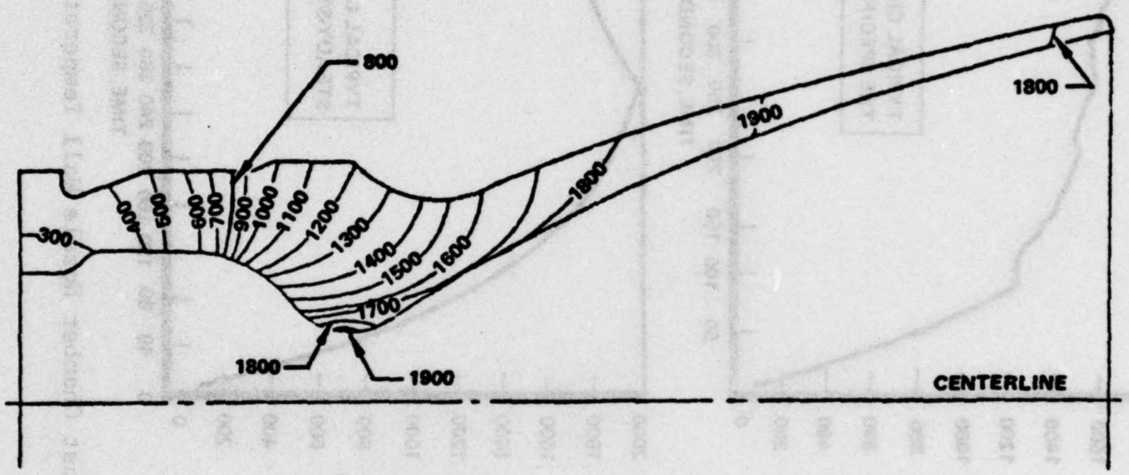


Figure 31. RS-14 Rocket Wall Temperatures, F, at the End of a Test Run (Beryllium Thrust Chamber)

TARGET ENGINE SYSTEM STRUCTURE

The target engine system structure design effort was performed by the Space Vector Corporation, Northridge, California, under subcontract to Rocketdyne. The structure was designed to readily accept the RS-14 or modified Atlas vernier engine subassembly, and included the engine attachment (thrust) structure; propellant tankage and pressurization bottle-mounting structures; attachment necessary for line, valve, and regulator mounting; and outer skin structure. Constraints for the design are shown in Table 9. The forward and aft stations of the structure were designed to provide a compatible structural interface with the booster and optical experiment stage.

Rocketdyne provided the internal interface data to allow Space Vector Corporation to design the structure details.

TABLE 9. MISSION CRITERIA (TARGET ENGINE SYSTEM DESIGN)

Launch Phase		
Shock, Vibration Acceleration	Minuteman I Specifications	
Experiment Phase	**Low Thrust**	**High Thrust**
Stabilization	3-Axis	
Propellant Settling, g-sec	0.1	
Number of Starts	5	5
Duration of Each Start, seconds	TBD	TBD
Total Firing Duration, seconds	TBD	20 to 25
Recovery Phase		
Impact Velocity, ft/sec	≤25	
Impact Attitude	Engine Nozzle-Down	

Structural design effort included investigation of launch environment effects on the design, including vibration, g-loading, and bending moment effects. Ground handling operations also were evaluated to ensure that the final design met all necessary ground-handling requirements.

Insulation requirements were reviewed to ensure that adequate thermal protection was provided for safe, predictable flight operation. Launch operational environmental effects, such as aerodynamic heating, boattail recirculation of exhaust gases, and exhaust plume impingement, were analyzed to ensure system compatibility.

A mass properties analysis was conducted, which included an evaluation of system total weight, component weights, center-of-gravity location, travel during the mission, and moment of inertia. The mass properties analysis identified potential variations to these parameters and the resulting effect on the final system design.

The target engine system primary structure consists of (1) an aluminum honeycomb thrust plate, (2) two U-shaped web sections, (3) two upper semicylindrical outer skins, (4) a lower riveted cylinder assembly, and (5) an aluminum honeycomb closure plate. All structure was fabricated from 6061-T6 aluminum alloy or 2024-T3 aluminum alloy (Fig. 32).

Both the honeycomb thrust plate and closure plate are 0.625 inch thick and 35.75 inches in diameter. The rocket engine assembly is mounted to the thrust plate through inserts installed in the plate. Three circular cutouts of 5.22-inch diameters each allow installation of three pressurant tanks to the aft side of the plate. A T-section ring is bolted to the plate periphery. Additional cutouts and in-place inserts allow installation of engine system components and instrumentation.

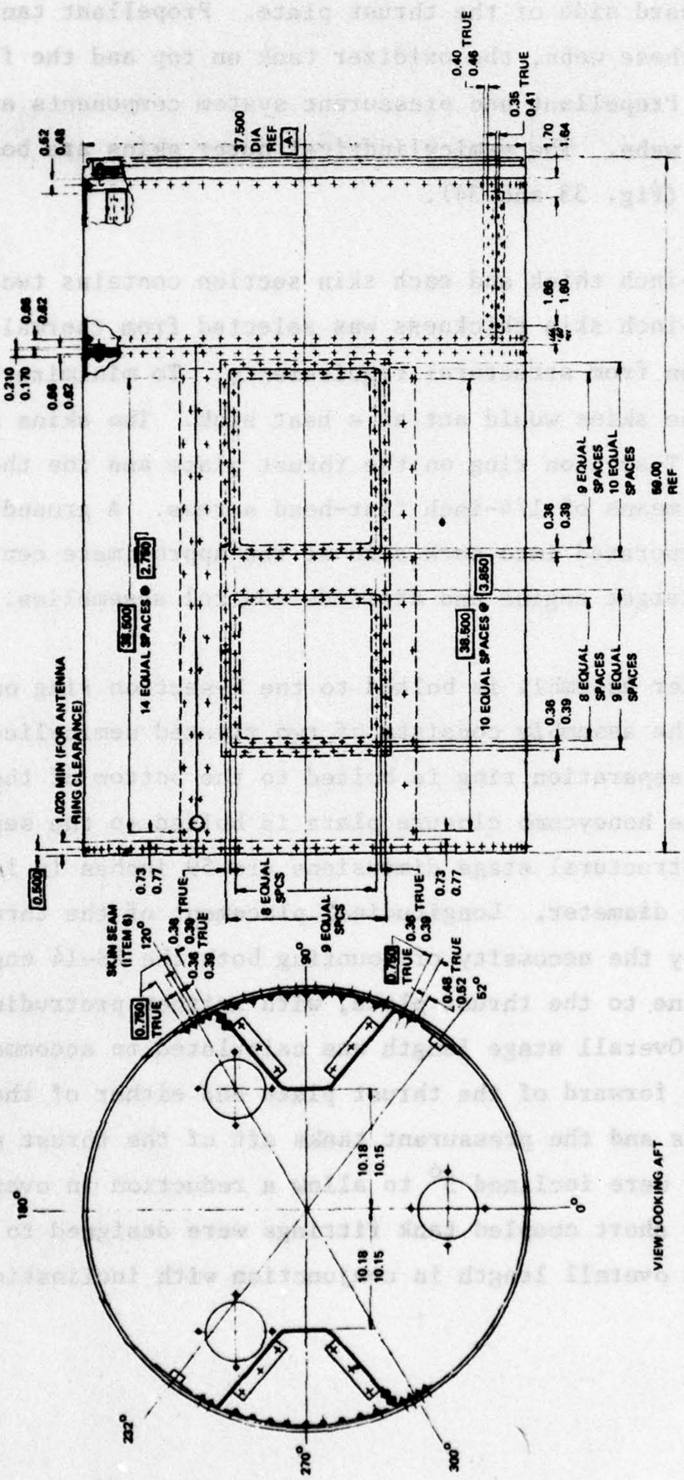


Figure 32. Target Engine System Primary Structure

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Two U-shaped web sections, 30.25 inches long and fabricated from 1/8-inch 6061-T6 Al alloy sheet, are bolted (180° apart) to the outer sectors of the forward side of the thrust plate. Propellant tanks are bolted between these webs, the oxidizer tank on top and the fuel tank on the bottom. Propellant and pressurant system components are attached to the webs. The semicylindrical outer skins are bolted to the web flanges (Fig. 33 and 34).

The skin is 1/4-inch thick and each skin section contains two access doors. The 1/4-inch skin thickness was selected from thermal consideration rather than from structural requirements. To minimize IR radiation effects, the skins would act as a heat sink. The skins are attached to the T-section ring on the thrust plate and the the U-section webs by means of 1/4-inch flat-head screws. A ground-handling fitting is incorporated into each skin at the approximate center of gravity of the target engine and attitude control assemblies.

The lower cylinder assembly is bolted to the T-section ring on the thrust plate. The assembly consists of two riveted semicylindrical outer skins. A separation ring is bolted to the bottom of the cylinder assembly, and the honeycomb closure plate is bolted to the separation ring. Overall structural stage dimensions are 59 inches in length and 37.500 inches in diameter. Longitudinal placement of the thrust plate was determined by the necessity of mounting both the RS-14 engine and the vernier engine to the thrust plate, with neither protruding past the stage end. Overall stage length was calculated to accommodate the propellant tanks forward of the thrust plate and either of the two engine assemblies and the pressurant tanks aft of the thrust plate. The propellant tanks were inclined 5° to allow a reduction in overall length. In addition, new short coupled tank fittings were designed to maintain the reduction in overall length in conjunction with inclination of the tanks.

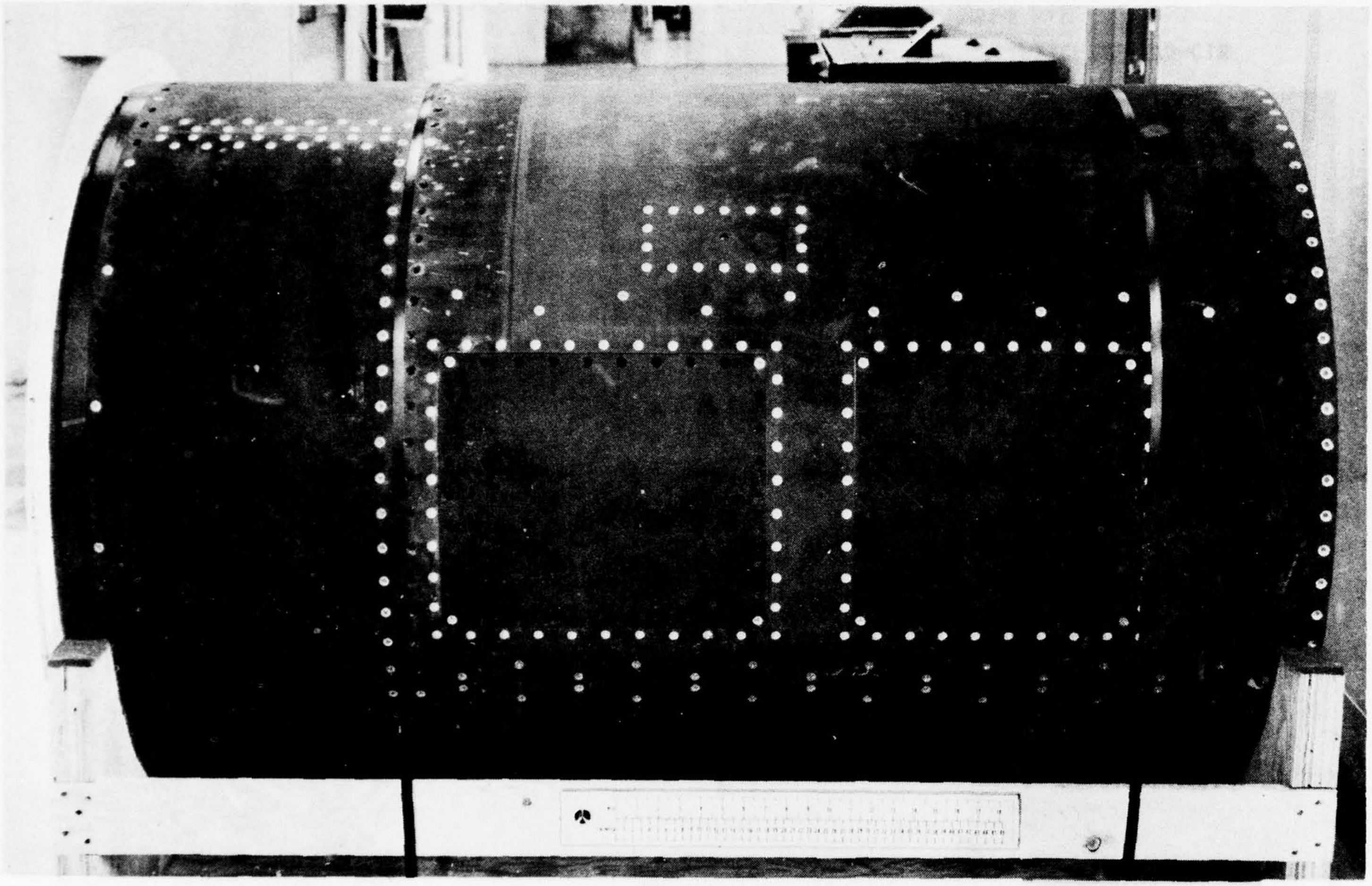

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Figure 33. Target Engine System TEM-1 Strcuture

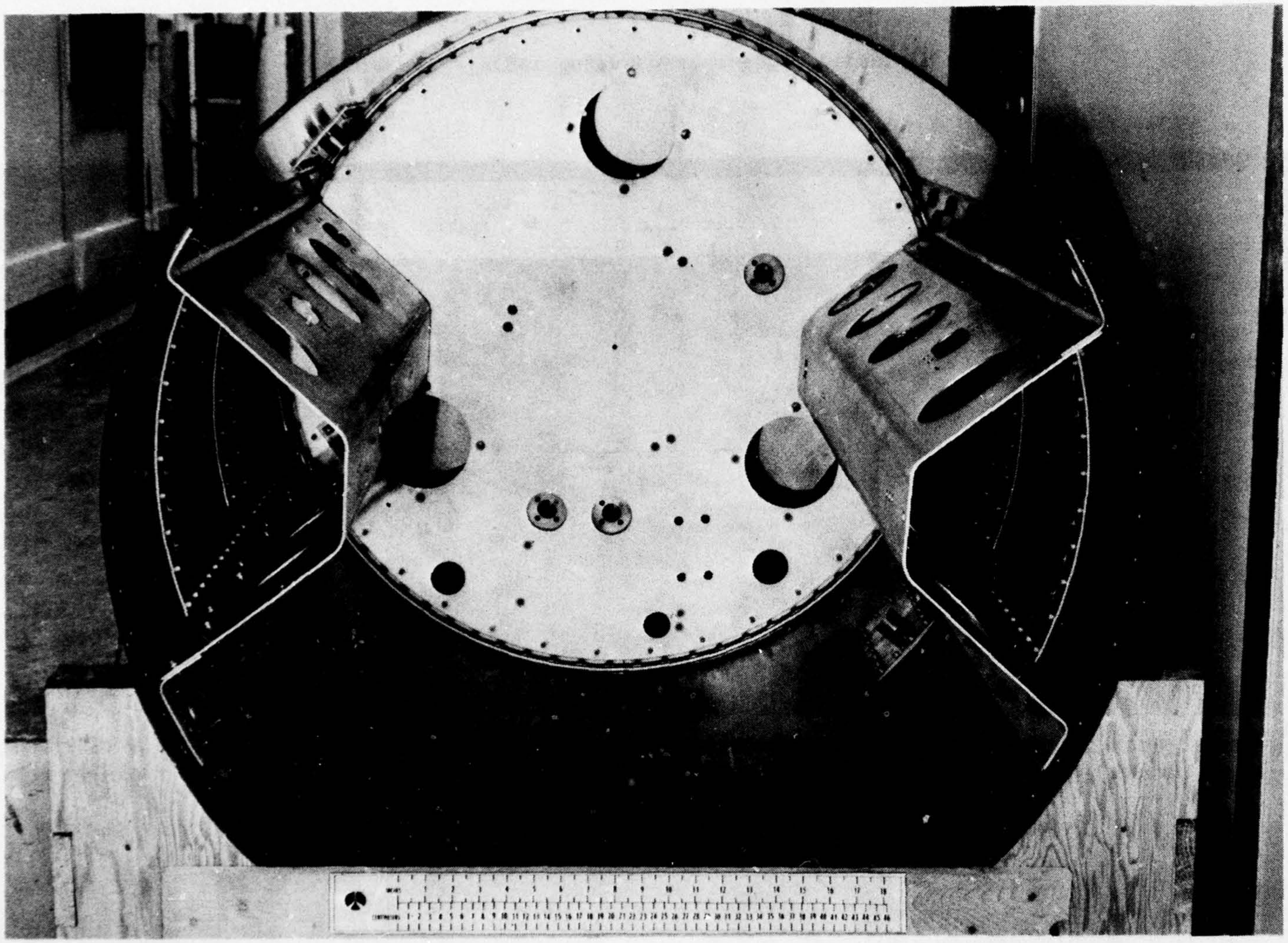

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Figure 34. Target Engine System TEM-1 Structure

Two slightly different closure plates were utilized, each having an opening consistent with either the RS-14 nozzle exit or the vernier engine nozzle exit. On TEM-3 a closure seal, consisting of an aluminum dish section and an asbestos cloth seal, was utilized to positively prevent exhaust gas recirculation into the stage. No closure seal was required on the RS-14 system.

RANGE SAFETY

For the TEM and HPTEM missions, involved range safety criteria are pre-launch safety, including the initial fill and pressurization operations, abort safety, and recovery safety, including decontamination and handling of the system after ground impact.

The efforts included in these tasks are defined using the guidelines provided by MIL-STD-882 and the ground safety and flight criteria as required by WSMR and VAFB in SANTECM-127-1, Range Safety Manual. The range safety task effort will be coordinated with the vehicle contractor, the launch operation personnel at WSMR and VAFB, and the Air Force Project Manager.

During the initial phase of the program, a report for the launch operations and recovery operations was prepared that clearly presented all efforts required for safety aspects in the launch and prelaunch operations including possible launch abort operations and in the recovery operations. The principal elements of this report are shown in Appendix B.

Range safety requirements are presented in Appendix B and are applicable to the TEM-1 and -2 and TEM-3 propulsion systems for field activities at WSMR and VAFB (SAMTEC). These requirements use detailed procedures developed at Rocketdyne during the R&D effort and appear in Appendix A.

Prelaunch	-	Checkout
Launch	-	Countdown/Abort
	-	Scrub/Recycle
	-	Flight
Recovery	-	WSMR only
Securing	-	WSMR only

Requirements for the Missile System Ground Safety Approval Package (MSGSAP) and system/subsystem description are presented in Appendix B for TEM system/subsystem.

Hazard and failure modes effect analyses were not prepared; however, hazardous condition and failure mode (single mode only) potentials were considered in hazardous operation -- equipment and procedure requirements are defined in Appendix B.

MOCKUP

The traditional means of designing a system are to prepare layouts in detail to provide the necessary clearances, component mounting, line routing, etc., to fit prescribed envelopes. This is acknowledged to be a good method and one that fills the need. As the system evolves, often it is necessary to go back to earlier work and modify it to accommodate a change or improvement. The very nature of the process is slow and certainly has the potential to be carried to completion with an unrecognized error (such as an interference).

The target engine system program was intended to be fast moving, especially during the design phase. Further, the design had to be iterative mainly because of the simultaneous search for flight-qualified components, structural detail and, as described elsewhere, the extensive selection of existing but surplus inventory.

To satisfy these requirements in a rapid, accurate, easily envisioned, readily changeable, and yet cost-effective fashion, a full-scale mockup of the target engine system was constructed. The materials selected were from readily available or obtainable stock and the hardware items used were, to the extent possible, actual hardware (even though not necessarily functional).

During the actual construction of the mockup, Space Vector Corporation design personel were on hand to take certain critical dimensions for positioning mounting holes, etc. This also allowed them to locate the vehicle electrical harness pass-through in an area that did not in any way interfere with the TES, per se.

Most important was the ability to locate the mounted position of transducers and service points within the structure so they would be accessible after assembly to perform necessary manual functions, such as installing an electrical connector. Location of the two access doors on either side of the stage was established using the mockup placement of squib valves, transducers and service valves.

Perhaps the greatest single benefit gained from the mockup was that the actual assembly of the target engine systems was accomplished easily and without any specialized training or familiarity with the unit by randomly chosen technicians. This allowed a great deal of flexibility and, at the same time, produced a consistent series of units.

The technique, because no drawings existed, was simply to copy the mockup to the greatest extent possible. No assembly problems arose during the course of fabrication that resulted from using the mockup itself.

The mockup was used for program review display. Each system detail was painted a characteristic color to identify the function; yellow for pneumatic, red for fuel, green for oxidizer systems, and blue for the elements representing structure.

The skin was made up of two pieces of 1/8-inch acrylic sheet and the access door outlines were marked with 1/16-inch wide white tape. (Figures 35 and 36) show the mockup and a completed unit, in this case TEM-1.

TARGET ENGINE SYSTEM ELECTRICAL INTERFACE

The objective of this subtask was to define electrical requirements for active control valves and instrumentation and provide the necessary interface information to the Air Force and Space Vector Corporation.

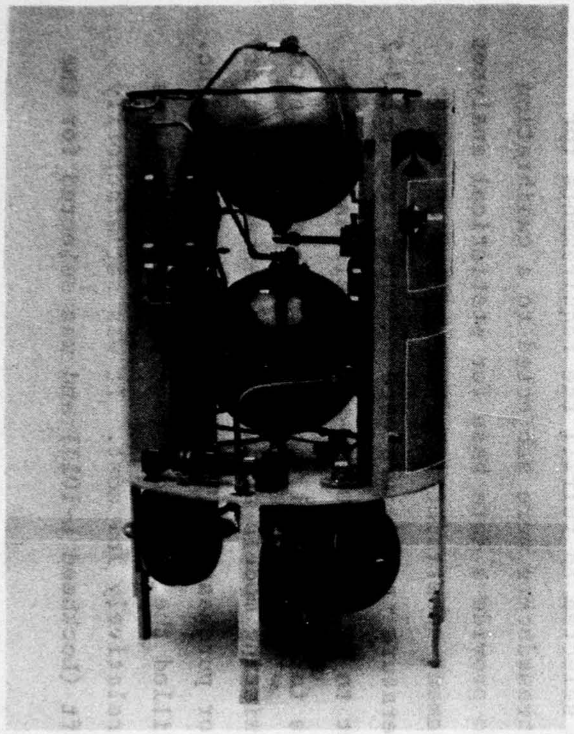

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Figure 35. TEM Mockup

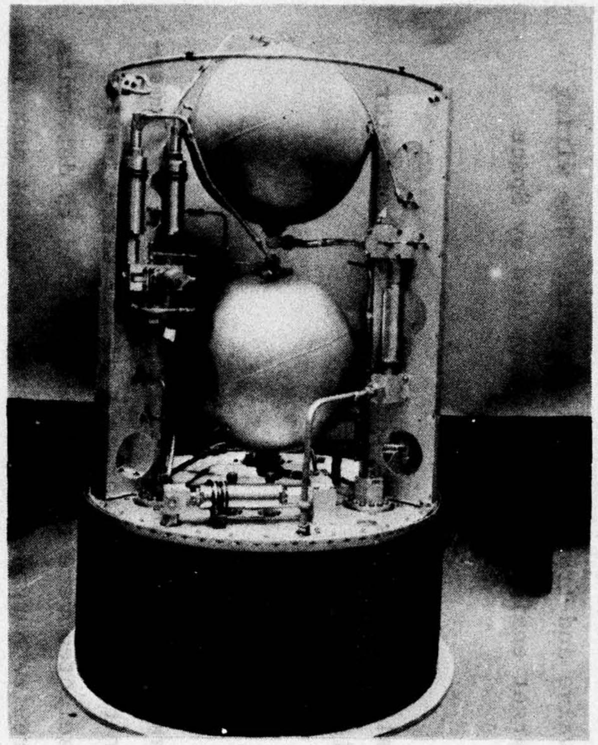

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Figure 36. TEM-1 Assembly

The preliminary design electrical interface for each target engine system was determined for the RS-14 and Atlas vernier engine systems. This electrical interface interface was defined as that occurring at the component connectors, i.e., valve and transducer components. The wiring harness for the ACS and target engine system was supplied by Space Vector.

The input and output signal requirements and the electrical connector schedule are shown in Tables 10 and 11.

Instrumentation

The goal of the program was to incorporate the minimum flight instrumentation required to monitor the flight performance of the target engine systems. The parameters selected were the minimum required to determine engine operation and for review purposes in the event of flight anomalies. Instrumentation equipment selection was made with consideration for (1) proven performance under similar conditions, (2) cost, and (3) availability. Inasmuch as a sufficient quantity of pressure transducers of appropriate ranges were available as excess inventory from Rocketdyne F-1 and J-2 engine programs, these were selected to fulfill the requirements for pressure transducers. The transducers were subjected to a calibration and several verifications to provide a data base for statistical analyses and determination of measurement uncertainty. Likewise, the GN_2 tank temperature resistance temperature transducers were selected from F-1/J-2 excess inventory and subject to LN_2 and H_2O ice-point resistance determinations. The requirements for the propellant temperature measurements could not be fulfilled by existing models available from excess inventory and therefore a selection for purchase was necessary. The Rosemount Inc. model 132GK transducer fulfilled the technical requirements as well as being readily available at relatively low cost. It was satisfactorily used on a commercial aircraft (Lockheed L-1011) and was selected for the

TABLE 10. TEM-1, -2 ELECTRICAL INTERFACES

Component	Electrical Interface			
	Signal, vdc		Connector	
	Input	Output	Component	Mating
Bipropellant Valve	28	-	Deutsch 77011-8-3PN-760-002	Deutsch 38068-9-3SN
Normally Closed Pyrotechnic Valve (GN_2 Tank)	↓	-	MS3101A10SL-4P (2 Each)	MS3108E10SL-4S MS3106E10SL-4S
Normally Closed Pyrotechnic Valve (NTO Tank)		-	MS3101A10SL-4P (2 Each)	MS3108E10SL-4S MS3106E10SL-4S
Normally Closed Pyrotechnic Valve (MMH Tank)		-	MS3101A10SL-4P (2 Each)	MS3108E10SL-4S MS3106E10SL-4S
Pressure Transducer (GN_2 Tank)		0 to 5	NA5-27286T5	MS3108E14S-6S
Pressure Transducer (Regulator Outlet)		↓	NA5-27286T5	MS3108E14S-6S
Pressure Transducer (NTO Supply Lines)			NA5-27286T5	MS3108E14S-6S
Pressure Transducer (MMH Supply Lines)			NA5-27286T5	MS3108E14S-6S
Temperature Transducer (GN_2 Tank)		-	MS33680(10SL-3P)	MS3106R10SL-3S
Temperature Transducer (NTO Tank)		-	Deutsch DL61H-8-3-PN	Deutsch DL66R-8-3-SN-1A
Temperature Transducer (MMH Tank)		-	Deutsch DL61H-8-3-PN	Deutsch DL66R-8-3-SN-1A
Thrust Chamber Pressure		0 to 5	NA5-27286T5	MS3108E14S-6S
Signal Conditioner (GN_2 Tank Temperature)		↓	MS3113H12-10P	MS3116E12-10S
Signal Conditioner (NTO Tank Temperature)			MS3113H12-10P	MS3116E12-10S
Signal Conditioner (MMH Tank Temperature)			MS3113H12-10P	MS3116E12-10S

TABLE 11. TEM 3 ELECTRICAL INTERFACES

Component	Electrical Interface			
	Signal, vdc		Connector	
	Input	Output	Component	Mating
Bipropellant Valve (4-Way Solenoid)	28	-	MS33648 and MS33681	MS3106E12S-3S
Normally Closed Pyrotechnic Valve (GN_2 Tank)		-	MS3101A10SL-4P (2 Each)	MS3108E10SL-4S MS3106E10SL-4S
Normally Closed Pyrotechnic Valve (NTO Tank)		-	MS3101A10SL-4P (2 Each)	MS3108E10SL-4S MS3106E10SL-4S
Normally Closed Pyrotechnic Valve (MMH Tank)		-	MS101A10SL-4P (2 Each)	MS3108E10SL-4S MS3106E10SL-4S
Normally Open Pyrotechnic Valve (NTO Feed Line Vent)		-	Pigtail	None
Normally Open Pyrotechnic Valve (MMH Feed Line Vent)		-	Pigtail	None
Pressure Transducer (GN_2 Tank)		0 to 5	NA5-27286T5	MS3108E14S-6S
Pressure Transducer (Regulator Outlet)			NA5-27286T5	MS3108E14S-6S
Pressure Transducer (NTO Supply Lines)			NA5-27286T5	MS3108E14S-6S
Pressure Transducer (MMH Supply Lines)			NA5-27286T5	MS3108E14S-6S
Temperature Transducer (GN_2 Tank)		-	MS33680-3(10SL-3P)	MS3106R1036-3S
Temperature Transducer (NTO Tank)		-	Deutsch DC61H-8-3-PN	Deutsch DC66R-8-3-SN-1A
Temperature Transducer (MMH Tank)		-	Deutsch DC61H-8-3-PN	Deutsch DC66R-8-3-SN-1A
Thrust Chamber Pressure		0 to 5	NA5-27286T5	MS3108E14S-6S
Signal Conditioner (GN_2 Tank Temperature)			MS3113H12-10P	MS3116E12-10S
Signal Conditioner (NTO Tank Temperature)			MS3113H12-10P	MS3116E12-10S
Signal Conditioner (MMH Tank Temperature)			MS3113H12-10P	MS3116E12-10S

NTO and MMH temperature measurements. The Rosemount Inc. model 510BH, solid-state signal-conditioning amplifier was properly trimmed to match the resistance temperature elements, and the temperature range desired was selected to condition and amplify signals from the temperature sensors. Table 12 lists the instrumentation equipment installed.

TARGET ENGINE SYSTEM SERVICING

The objective of this subtask was to establish target engine system servicing requirements which utilize the RS-1401 and the Atlas vernier engine systems. Procedures were analyzed and defined to ensure that they were compatible with the mission analysis requirements and range and operational safety.

Procedures have been provided in Appendix A that cover maintenance and servicing of the Target Engine System and the operation and servicing of the propellant service carts.

DESIGN REVIEW

The objective of this task was to present a detailed design review of the results of Task I. There were two reviews: a Preliminary Design Review (PDR) at which time Air Force approval to purchase long-lead items was granted (17 November 1975), and the Critical Design Review (CDR) presented on 29 January 1976. The detail design prepared in Task I, including the analysis efforts which were conducted or utilized from available data; the propellant servicing cart selection, design modifications, and supporting analysis; and the Task III test plan were presented verbally to the Air Force Program Manager at Rocketdyne as the Critical Design Review.

The Air Force Program Manager gave approval to proceed with the fabrication, assembly, and test phases of the program.

TABLE 12. TEM INSTRUMENTATION

Parameter	Range		Model No.		Uncertainty	Response	Source
	TEM-1, -2	TEM-3	TEM-1, -2	TEM-3			
GN_2 Tank Pressure	0 to 3500 psi	0 to 3500 psi	NA5-27412T35T	NA5-27412T35T	±2%	100 Hz	Rocketdyne - J2 Excess
Regulator Out Pressure	0 to 500 psi	0 to 1000 psi	NA5-27412T5T	NA5-27440T10T	±2%	100 Hz	Rocketdyne - J2/F1 Excess
MMH Supply Pressure	0 to 500 psi	0 to 1000 psi	NA5-27412T5T	NA5-27440T10T	±2%	100 Hz	Rocketdyne - J2/F1 Excess
NTO Supply Pressure	0 to 500 psi	0 to 1000 psi	NA5-27412T5T	NA5-27440T10T	±2%	100 Hz	Rocketdyne - J2/F1 Excess
Combustion Chamber Pressure	0 to 200 psi	0 to 500 psi	NA5-27316T2T	NA5-27412T5T	±2%	100 Hz	Rocketdyne - J2 Excess
GN_2 Tank Temperature	-200 +500 F	-200 +500 F	NA5-27215T3	NA5-27215T3	±0.25 F	63% < 0.2 Seconds	Rocketdyne - J2 Excess
MMH Temperature	0 to 300 F	0 to 300 F	132 GK	132 GK	±2.0 F	63% < 5 Seconds	Purchase - Rosemount Inc.
NTO Temperature	0 to 300 F	0 to 300 F	132 GK	132 GK	±2.0 F	63% < 5 Seconds	Purchase - Rosemount Inc.
Signal Condition (3-Temperatures)	0 to 5 Vdc	0 to 5 Vdc	510 BH	510 BH	±0.6%	3 Hz	Purchase - Rosemount Inc.

TASK II: FABRICATION AND ASSEMBLY

The primary objective of this task was to fabricate and assemble three target engine systems. A secondary objective was to modify and demonstrate satisfactory operation of the LR101-NA-7 Atlas vernier engine with NTO and MMH propellants. An additional secondary objective was to fabricate the propellant service carts to be used in tanking and servicing the TEM at WSMR and VAFB.

The operational flow path for fabrication and assembly of each TEM is shown in Fig. 37. Activity on the fabrication and assembly of all subsystem elements began after approval of the Task I designs with the exception of the structure. Since the structure was designed as a unique item, the fabrication and assembly of its details began early in the program to satisfy schedule constraints. Earlier review and approval of the vernier engine modifications was required so that additional time could be available to demonstrate satisfactory propellant conversion. In addition, the early demonstration eliminated test interference between the vernier engine firings and verification tests of TEM-1 at CTL-4, test stand 24. Both units were tested on the same stand as a cost minimizing effort.

COMPONENTS

Following approval of Task I design, procurement of subsystem elements was initiated. All major components, with the exception of the structure, were available as previously produced and flight-qualified hardware. These items required only processing of purchase orders since the specifications and/or part numbers were already established. Early approval was also proposed for release of long-lead time components. This approval, like the earlier vernier modification approval, ensured that test and flight schedules could be maintained. Further, insofar

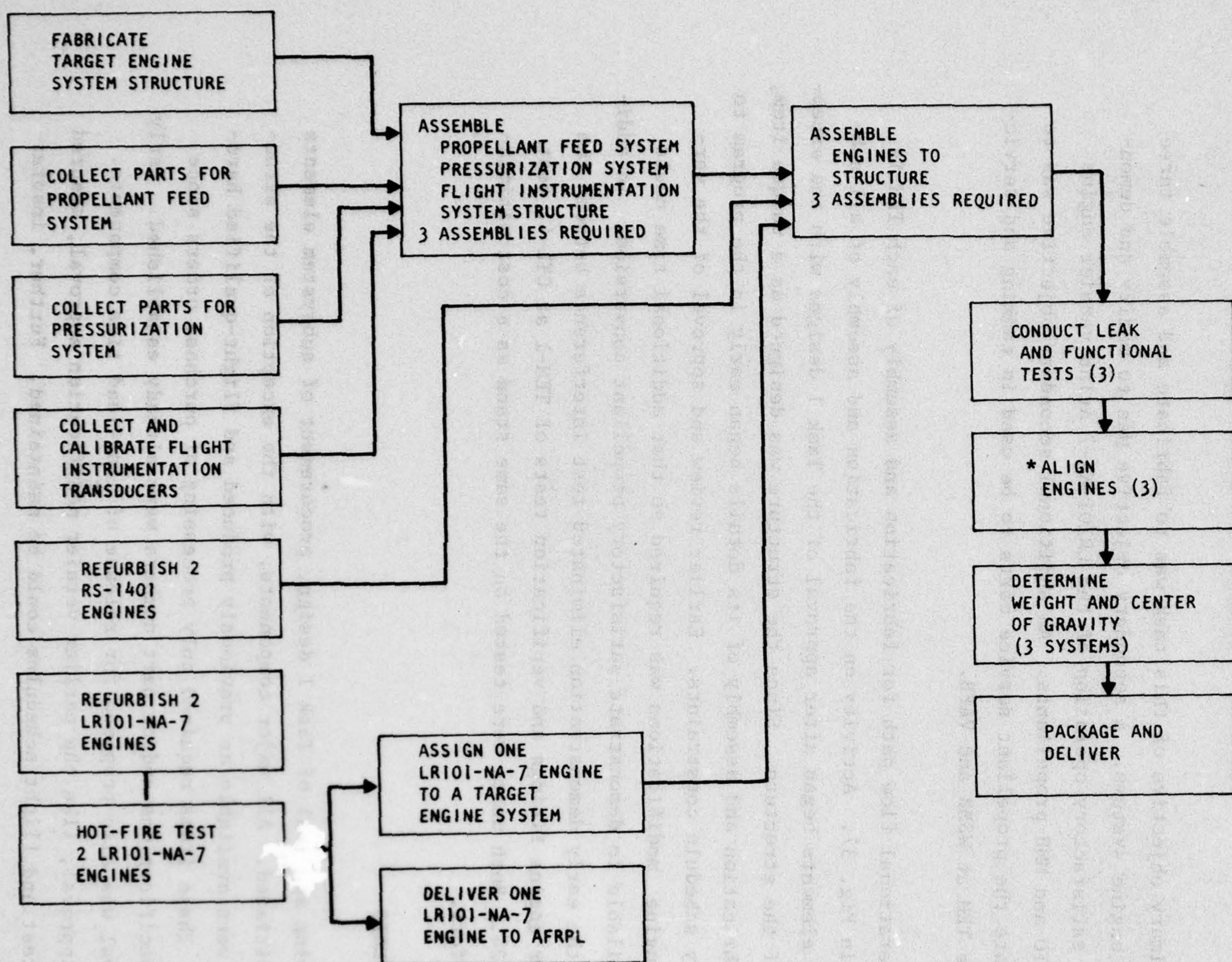

Figure 37. Fabrication and Assembly of Target Engine Systems Flow Diagram

as specific components were identified that satisfied the system requirement and were available from excess government inventory, they too were presented for early approval for use. This also ensured the schedule maintenance.

ASSEMBLY OF TARGET ENGINE SYSTEMS

The three target engine systems (TEM-1, -2, and -3) were assembled by the Engineering Development Laboratory. Prior to assembly, critical components underwent functional tests to complement testing performed by the vendor. Each structure was set on a build frame and the components installed (see section on mockup). Minor supporting brackets and tubing runs were done on an individual assembly basis. All tooling required was "soft," i.e., experimental in design and concept. With the engine installed and with the system burst diaphragms installed, a leak and functional test was made at reduced pressure.

A "dry" center of gravity was determined using two platform scales. The engine was aligned to the engine/thrust structure interface. Since the intent of alignment is to minimize the misalignment of the thrust vector with respect to total system center of gravity, and since the total system will ultimately have another module mated, it may be resolved to change the alignment at such time as the total system center of gravity has been determined.

The final dry weight was recorded with adjustment being made for the squib valves, which were not installed at this time.

The complete assembly was then packaged for delivery to SSFL.

MODIFIED VERNIER ENGINE TESTING

Two modified MA-3 Atlas vernier engines were assigned to the program: one was to be used to demonstrate the suitablility of the storable propellant combination, and the other was to be hot fired and retained for installation in TEM-3.

A detailed test plan was generated with the following general objectives:

- Evaluate vernier engine assembly start and stop transients
- Determine steady-state performance
- Evaluate combustion stability characteristics
- Evaluate propellant decontamination procedure
- Determine hardware durability

Predicted target nominal performance parameters for these tests are shown in Table 13. The configuration of the modified vernier engine assembly as tested is shown schematically in Fig. 38, and instrumentation requirements are listed in Table 14. Test matrix requirements are detailed in Table 15. Detailed decontamination procedure for the vernier engine assembly was specified, and motion picture coverage also was detailed.

One of the biggest unknowns regarding the success of this program was the effect of storable propellants on the modified vernier engine (VE) assembly. Early assessment of potential problem areas--combustion instability, reaction of MMH with the thrust chamber cooling jacket materials (copper spiral wire, braze compound, etc.) and poor performance--was of paramount importance. Of operational concern was whether post-hot-fire purges were required as this would have a significant impact on stage design requirements. The effect of an extended oxidizer lead was also a concern.

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TARGET ENGINE SYSTEMS.(U)
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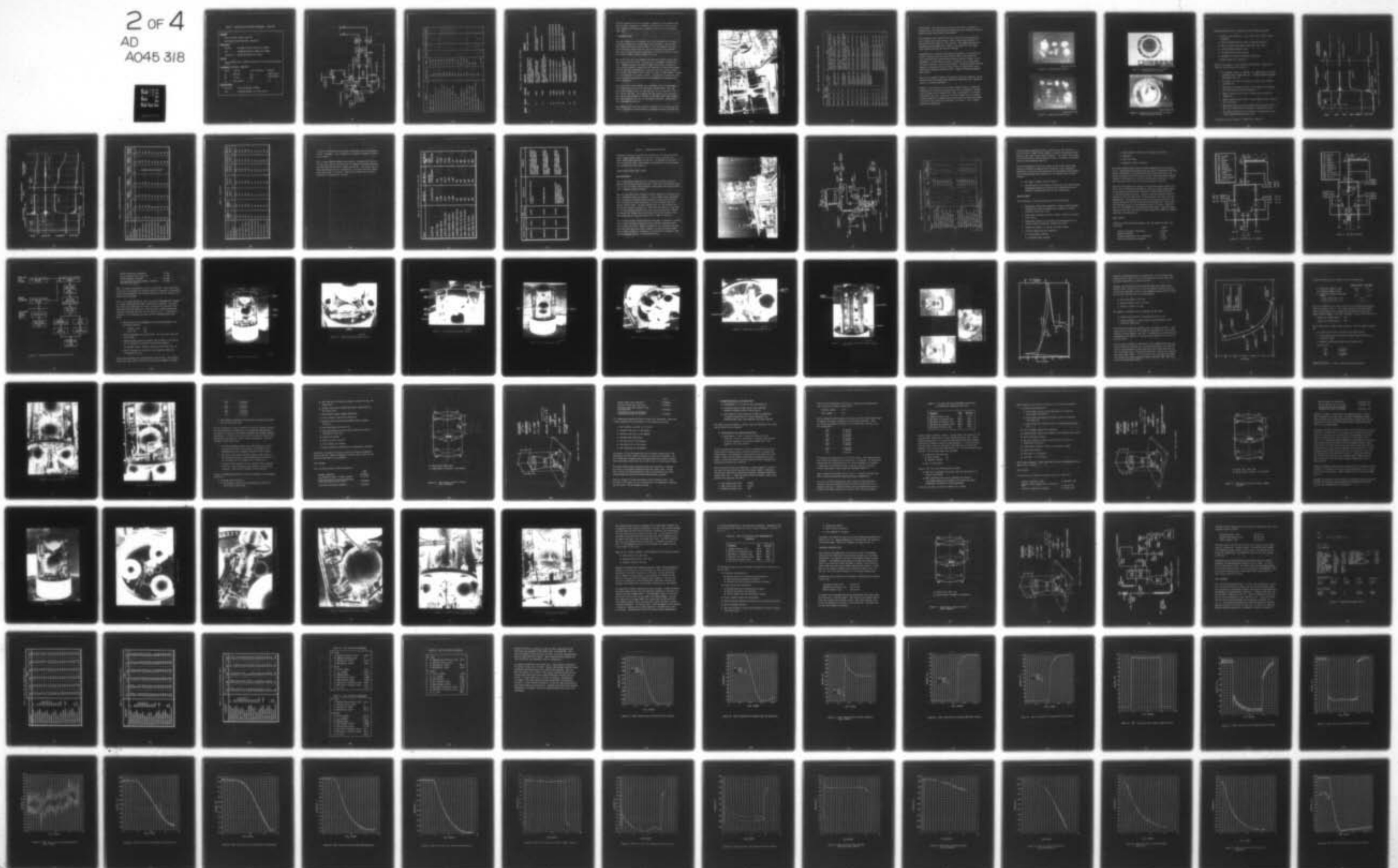

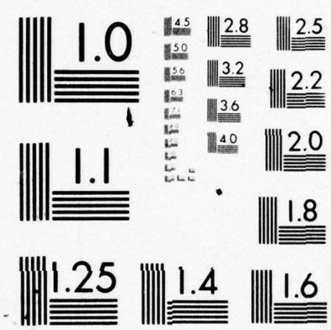

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 13. MODIFIED ATLAS VERNIER PERFORMANCE - PREDICTED

<u>HARDWARE</u>

Vernier engine assembly modified

Hydromatics propellant valve, NA5-26312

<u>PROPELLANTS</u>

Oxidizer	Nitrogen Tetroxide (NTO) MIL-P-27404
Fuel	Monomethylhydrazine (MMH) MIL-P-25508
Pressurant	Gaseous Nitrogen MIL-P-27401

<u>MISSION</u>

Five 5-second bursts, total 25 seconds burn time during 15-minute flight

<u>PERFORMANCE</u> (ALTITUDE, PREDICTED)

Thrust	1150 lbf	Inlet Pressures	630 psia
P_c	358 psia	$\dot{W}_{ox}$	3.077 lb/sec.
MR	1.6 o/f	$\dot{W}_{fu}$	1.923 lb/sec.
I_s	230 seconds	ε	5.6

<u>DECONTAMINANTS</u>

Oxidizer	Freon Solvent MIL-C-81302
Fuel	Isopropyl Alcohol TT-I-735, Grade A

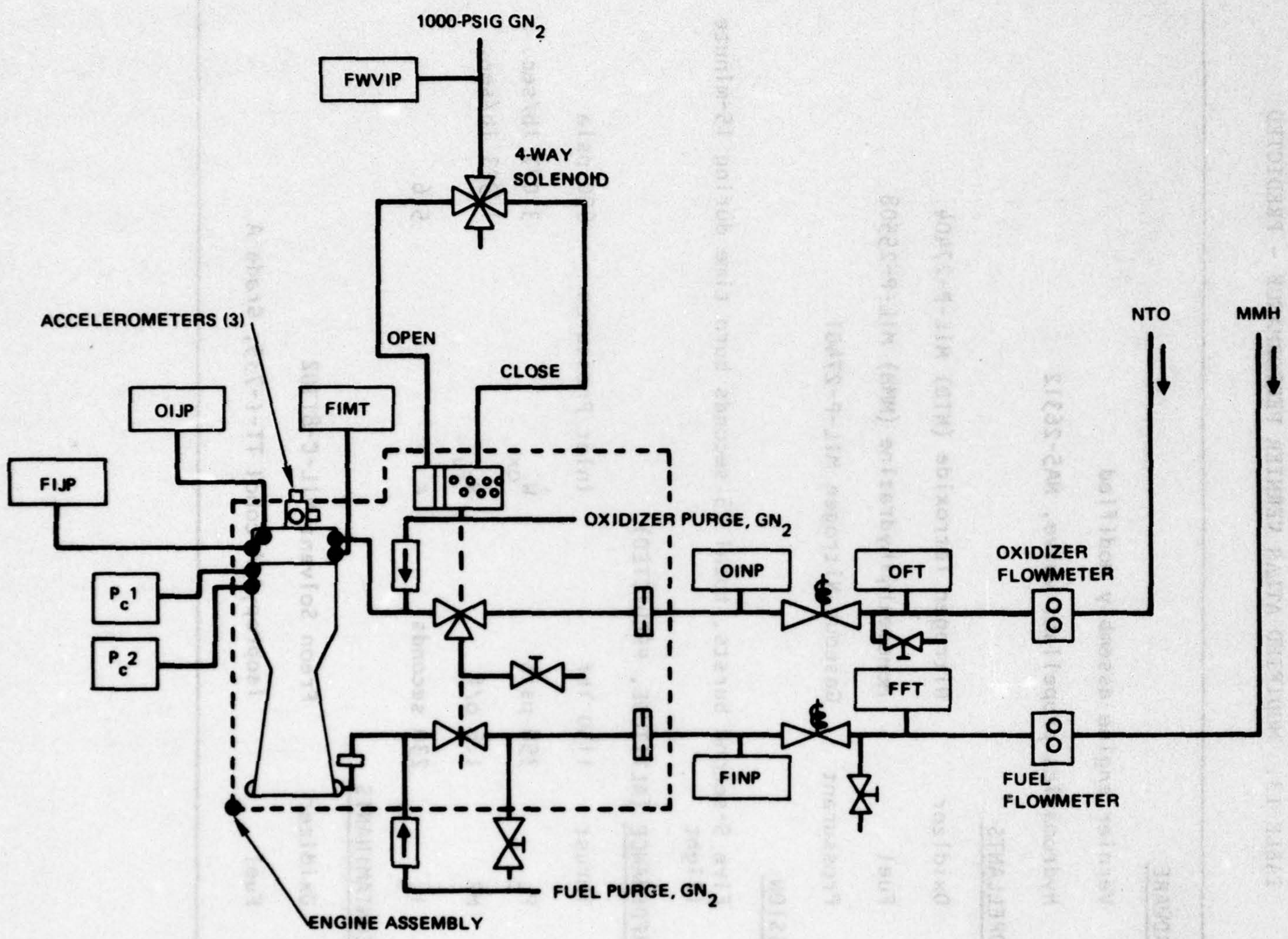

Figure 38. Modified Atlas Vernier Hot Fire Test Setup

TABLE 14. MODIFIED ATLAS VERNIER TEST - INSTRUMENTATION

Parameter	Identification	Range	Digital	FM Tape	Oscillograph	DIGR
Chamber Pressure, psig	P_{c1}	0 to 400	X			X
Chamber Pressure, psig	P_{c2}	0 to 400		X	X	
Oxidizer Injection Pressure, psig	OIJP	0 to 600	X	X	X	
Fuel Injection Pressure, psig	FIJP	0 to 600	X	X	X	
Oxidizer Orifice Inlet Pressure, psig	OINP	0 to 750	X			X
Oxidizer Valve Inlet Pressure, psig	OVINP	0 to 750	X			X
Fuel Orifice Inlet Pressure, psig	FINP	0 to 750	X			X
Fuel Valve Inlet Pressure, psig	FVINP	0 to 750	X			X
Four-Way Valve Inlet Pressure, psig	FWVIP	0 to 1000				X
Oxidizer Flowmeter, gpm	OFM	0 to 20	X		X	
Fuel Flowmeter, gpm	FFM	0 to 20	X		X	
Oxidizer Flowmeter Temperature, F	OFT	30 to 150	X			
Fuel Flowmeter Temperature, F	FFT	30 to 150	X			
Fuel Injector Manifold Temperature, F	FIMT	0 to 500	X		X	
Radial Accelerometer, g (0 to peak)	RA	250		X		
Axial Accelerometer, g (0 to peak)	AA	250		X		
Tangential Accelerometer, g (0 to peak)	TA	250		X		
Start/Stop Signal	S/S		X	X	X	
Thrust, lbf	F	0 to 1500	X		X	

TABLE 15. MODIFIED ATLAS VERNIER - TEST MATRIX

ENGINE	TEST NO.	DURATION	OBJECTIVES	COMMENTS
-V	1-1	5 SEC.	CALIBRATION, DRY JACKET START, BLED FACILITY LINES. JACKET DELTA-T AND FLOW DATA. START/STOP TRANSIENTS.	PURGE JACKET POSTTEST
	1-2	5 SEC.	M.R. = 1.6 PERFORMANCE, BLED FACILITY LINES. START/STOP TRANSIENTS.	TARGET 1.6 M.R. USING ADJUSTED INLET PRESSURES.
	1-3	25 SEC.	M.R. = 1.6 WITH BALANCED INLET PRESSURES. JACKET DELTA-T MARGIN. DRY JACKET START, BLED FACILITY LINES.	RE-ORIFICE PRE-TEST
	1-4	30 SEC.	110% NOMINAL INLET PRESSURE	CHANGE FACILITY TANK PRESSURES
	1-5	30 SEC.	90% NOMINAL INLET PRESSURE	CHANGE FACILITY TANK PRESSURES
	1-6	5 SEC.	110% NOMINAL M.R. (1.76 O/F)	CHANGE FACILITY TANK PRESSURES
	1-7	5 SEC.	90% NOMINAL M.R. (1.44 O/F)	CHANGE FACILITY TANK PRESSURES
	1-8	25 SEC.	MISSION DUTY CYCLE SIMULATING ALTITUDE RESTARTS. VERIFY HARDWARE DURABILITY.	ASPIRATE ENGINE PROPELLANTS BETWEEN RESTARTS.
-3	2-1	5 SEC.	PERFORMANCE CALIBRATION (FLOW DELTA-P DATA)	
	2-2	5 SEC.	M.R. = 1.6 WITH BALANCED INLET PRESSURES	RE-ORIFICE AS REQUIRED

Hot-fire testing of the first assembly, commenced in late November 1975. This assembly, designated -V assembly, was installed in the test stand with attendant instrumentation, propellant supply, and purge hardware (Fig. 39).

-V ENGINE HOT FIRE

Test 001, conducted on 24 November 1975, was terminated at 0.1 second by high P_c redline due to high engine inlet pressures. The test was shut down in the start transient when P_c read approximately 440 psig and essentially resulted from the facility propellant tank pressure being set too high from misinterpretation of facility ΔP data. No vernier engine assembly hardware damage was noted.

The second test, 002, was conducted the same day as 001 but after both tank pressures were reduced. The test was a programmed 5-second duration. Chamber pressure was slightly higher than target, and mixture ratio was low; however, enough data were generated to characterize engine assembly and test stand hydraulic resistances for more accurate subsequent setups. (See Table 16 for a summary of tests on this engine.) Purges at cutoff resulted in a smooth shutdown. Following the second test, the engine assembly was decontaminated and disassembled for component condition assessment.

Leak tests on the valve assembly were performed, prior to disassembly, to determine ball seat seal and shaft seal leakage rates. Seat and shaft seal leakage on the fuel side was zero at test pressures of 30, 200, and 700 psig GN_2. The oxidizer side was tested at the same pressure levels; zero leakage was recorded on the shaft seals and a maximum ball seal leakage of 60 cc/hr was recorded at 700 psig. Leakage data were considered satisfactory.

Disassembly of the fuel side showed all hardware to be in excellent condition. The Buna-N O-rings exposed to propellants showed no evidence of

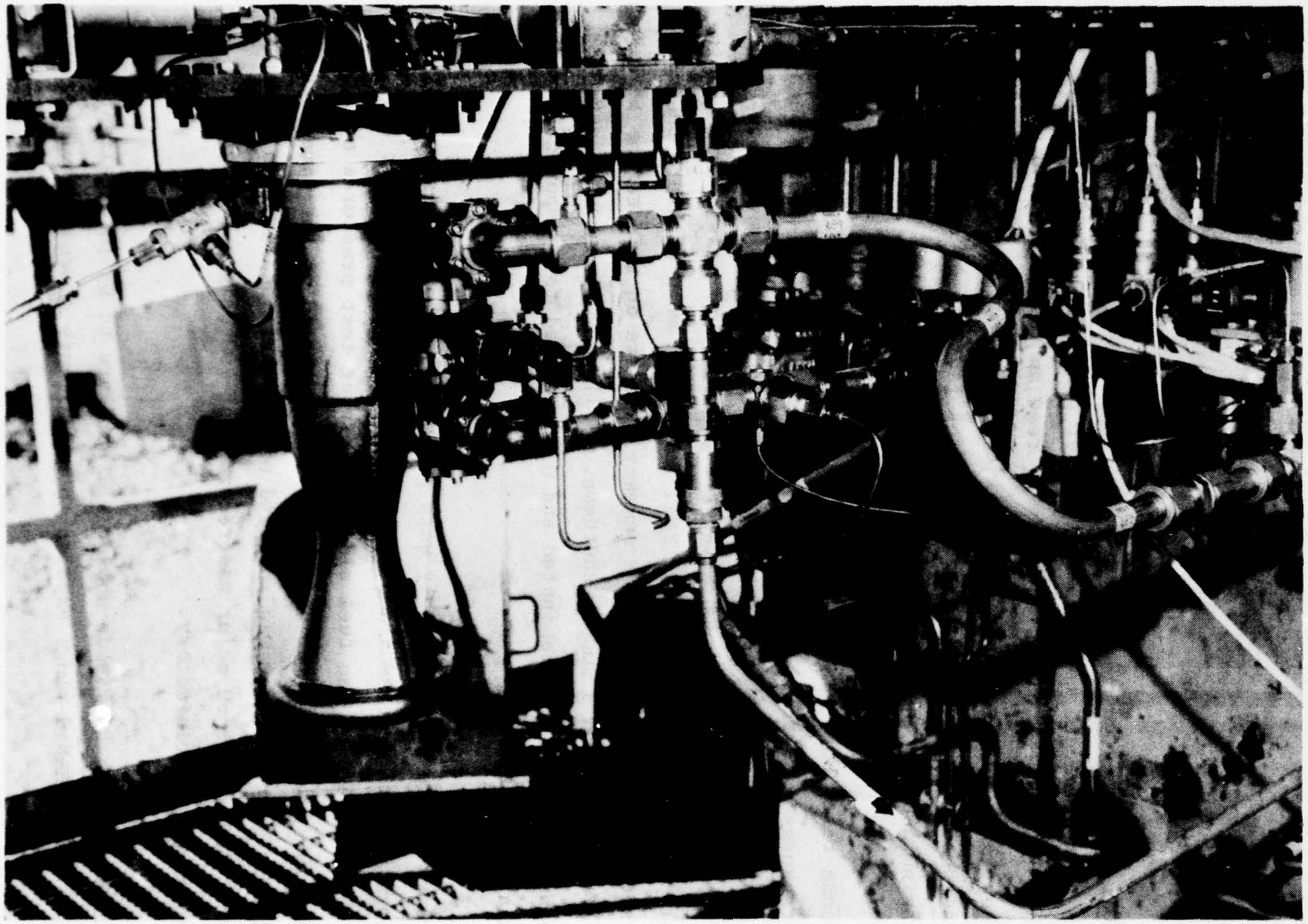

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Figure 39. -V Engine Assembly Installed in CTL-4, Stand 24A

TABLE 16. MODIFIED ATLAS VERNIER (-V) HOT-FIRE TESTS

Test No.	Test Data, 1975	Test Duration, Seconds	Objectives	Results
846-001-75	11/24	0.1	Check out test	Satisfactory test cutoff by high P_c: Tank pressures too high. Smooth start: 40 ms oxidizer lead dry jacket start. No purge at cutoff. Smooth shutdown.
846-002-75	11/24	5.0	Calibration test for REA and facility ΔP data	Satisfactory test. Smooth start: 30 ms oxidizer lead purges at cutoff. Smooth shutdown. Hardware OK.
846-003-75	12/5	5.0	REA performance test	Satisfactory test smooth start: 35 ms oxidizer lead. No purges at cutoff. Smooth shutdown. P_c and MR close to nominal values.
846-004-75	12/5	25.0	REA performance test and jacket cooling margin evaluation	Satisfactory test. Wet jacket start resulted in 15 ms oxidizer lead. Smooth start transient. Purges at shutdown: Slight buzz. Fuel manifold temperature rose to +200 F, stabilized in 6 seconds. Hardware OK.
846-005-75	12/11	30.0	Performance gain test-110% of nominal inlet pressure	Satisfactory test. No astrodata output. Feed lines not bled prior to test: Smooth start.
846-006-75	12/11	30.0	Performance gain test-110% of nominal inlet pressures	Satisfactory test: Repeat of test 006 for astrodata output. Start cutoff transients OK.
846-007-75	12/11	30.0	Performance gain test-90% of nominal inlet pressures	Satisfactory test. Smooth start: 50 ms oxidizer lead. Slight buzz at shutdown with purges.
846-008-75	12/11	10.0	Performance gain test-110% of nominal MR	Satisfactory test. Smooth start: 40 ms oxidizer lead. Slight buzz at shutdown during purge period.
846-009-75	12/11	10.0	Performance gain test-90% of nominal MR	Satisfactory test. Smooth starts: 35 mx oxidizer lead. Slight buzz at shutdown during purge period.
846-010-75	12/11	5.0	Mission duty cycle at nominal P_c and MR fuel jacket aspirated between burns	Satisfactory test. Smooth start: 35 mx oxidizer lead. Buzz at cutoff with oxidizer only purge.
846-011-75	12/11	5.0		Satisfactory test. Smooth start: 45 ms oxidizer lead. Buzz at cutoff with oxidizer only purge.
846-012-75	12/11	5.0		Satisfactory test. Smooth start: 15 ms oxidizer lead. Buzz at cutoff with oxidizer only purge.
846-013-75	12/11	5.0		Satisfactory test. Smooth start: 10 ms oxidizer lead. Buzz at cutoff with oxidizer only purge.
846-014-75	12/11	5.0		Satisfactory test. Smooth start: 0 ms oxidizer lead. Smooth cutoff.

NOTE: Simulated mission duty cycle is tests -010 through -014 deterioration. The internal cavities were clean with no evidence of residual fuel, verifying adequate decontamination and flushing procedures. Figure 40 shows the fuel-side valve details.

On the oxidizer side, Buna-N O-rings were used at the bleed port plug and the purge check valve fitting. Both O-rings showed evidence of deterioration from exposure to the oxidizer. No leakage problems were experienced during engine test, however, the bleed port plug O-ring failed (separated) when the plug was removed.

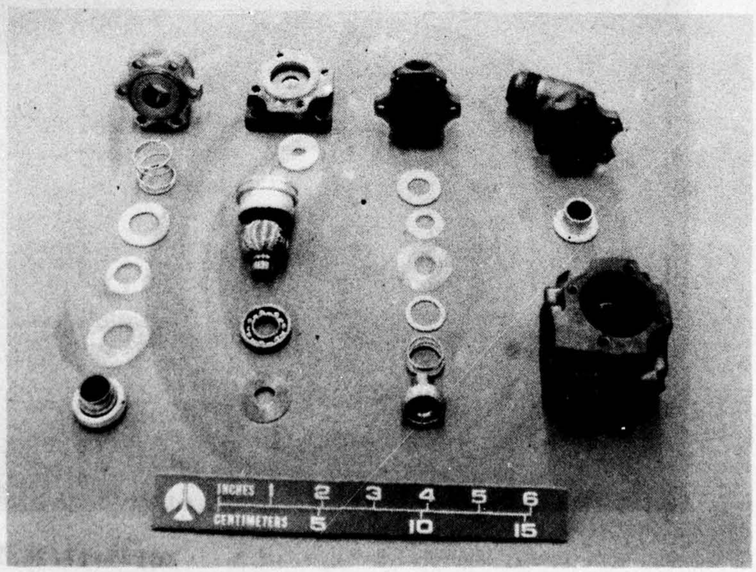
Disassembly of the oxidizer side showed the hardware to be in good condition. The Kel-F ball seal and the Mylar shaft seals showed very little deterioration from propellant exposure and were reused on valve reassembly. A slight whitish residue, verified to be aluminum oxide, was noted on several of the internal details. The green anodized surfaces exposed to propellants were also discolored to a copper-bronze color. There was no evidence of surface attack. Figure 41 shows the oxidizer-side details.

Based on the hardware condition following two hot-fire exposures, it was concluded that the current valve design was satisfactory for limited exposure to storable propellants.

Removal of the injector from the thrust chamber showed no significant degradation of the Buna-N O-rings between the two components; however, these O-rings will be replaced after short term exposures to storable propellants (Fig. 42). Likewise, the thrust chamber was in excellent condition (Fig. 43), although some surface marks resulting from combustion effects were noted just upstream of the throat. The -V vernier engine was reassembled.

1GT65-12/1/75-C2B*

Figure 40. Fuel-Side Valve Details



1GT65-12/1/75-C2A*

Figure 41. Oxidizer-Side Valve Details

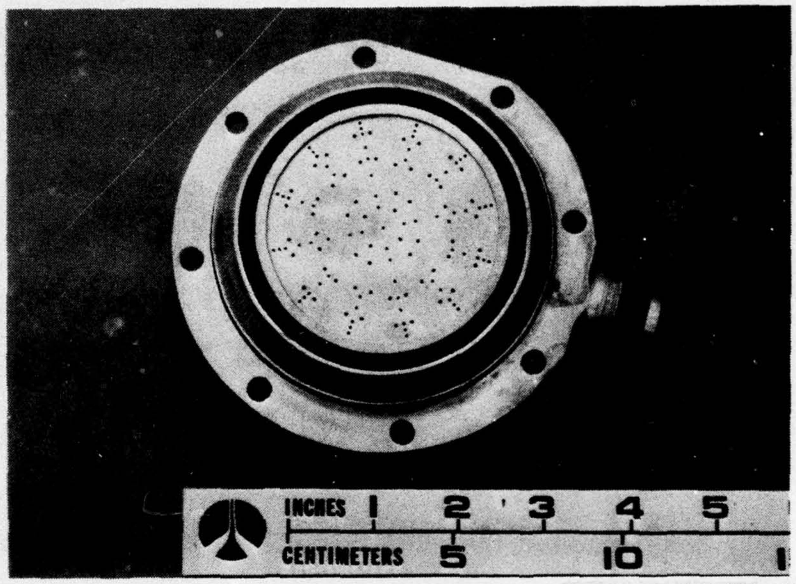


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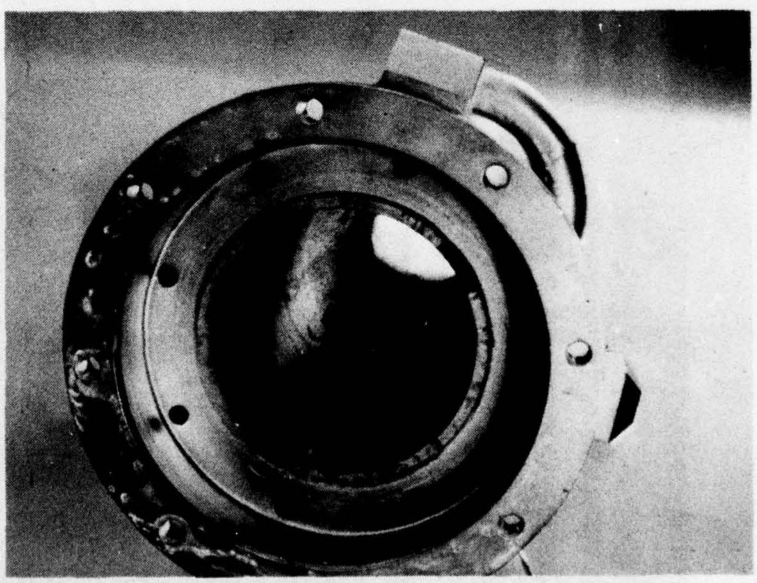
Figure 42. Modified Vernier Engine Injector Following Hot-Fire Testing



1GT25-11/26/75-C1B

Figure 43. Modified Vernier Engine Thrust Chamber Following Hot-Fire Testing

Testing continued on the -V engine with the following objectives:

- Effect of wet jacket (i.e., fuel jacket full of MMH) on start transient
- Effect of purge versus no purge in shutdown transient
- Effect of bled versus nonbled propellant inlet lines
- ±10% from nominal mixture ratio
- ±10% from nominal inlet pressure
- Determine fuel injection manifold temperature
- Mission duty cycle simulation

Based on the results of tests 846-003 through 846-014, summarized in Table 16, the following was concluded:

1. No shutdown purges are required. The engine exhibits a smooth shutdown without purges (Fig. 44). Slight roughness was noted with purges (Fig. 45).
2. The engine will start satisfactorily with a slight oxidizer lead (Fig. 44)
3. There was no discernible effect of bled versus nonbled propellant feed lines on the start transient
4. Engine operation within ±10% of nominal inlet pressure was satisfactory
5. Engine operation within ±10% of nominal mixture ratio (1.6 o/f) was satisfactory
6. MMH temperature at injection manifold did not exceed 244 F on any of the tests--this was considered a satisfactory limit
7. The engine demonstrated the capability to satisfactorily complete a simulated mission duty cycle

Performance of the -V engine is tabularized in Table 17.

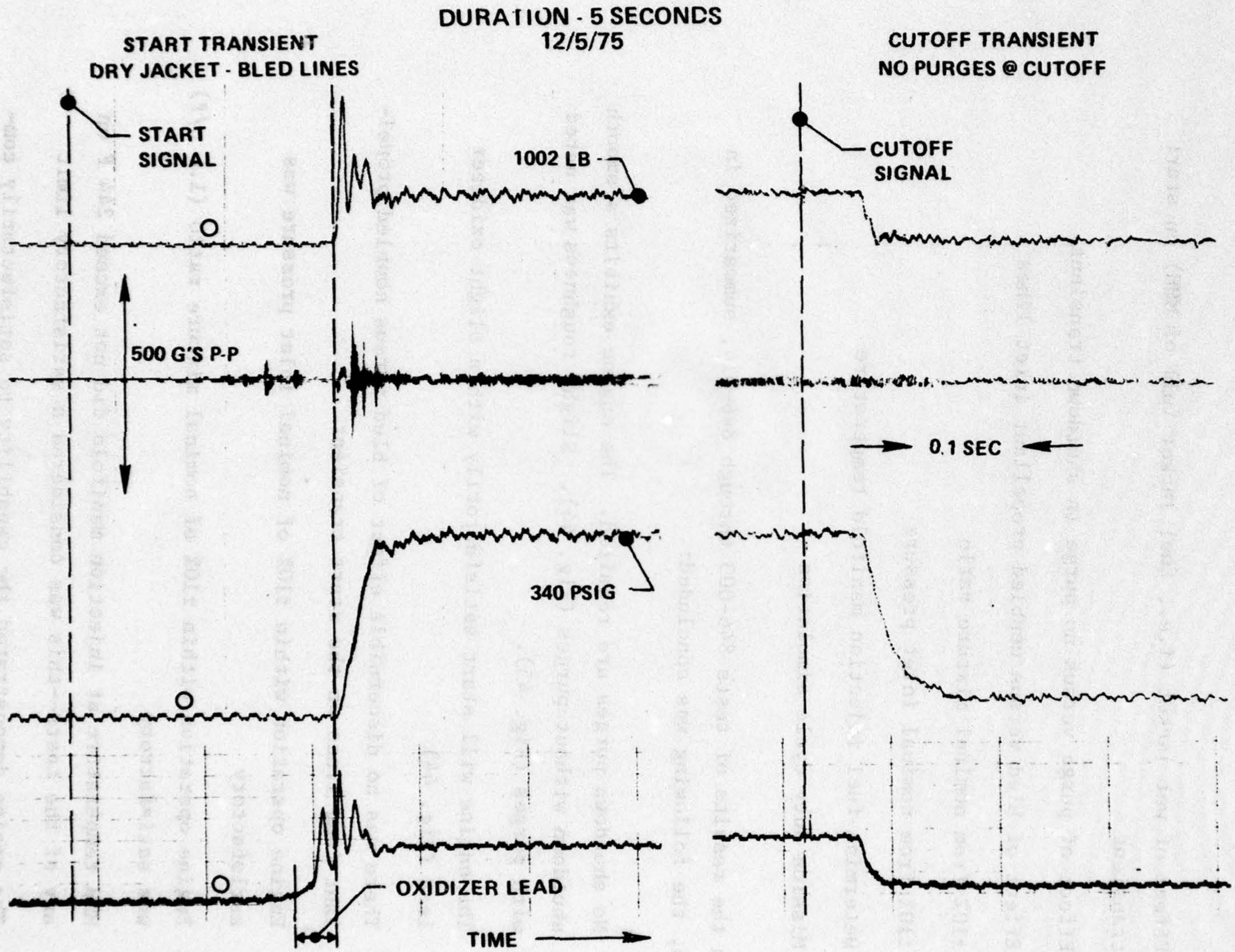


Figure 44. Modified Vernier (-V) Engine (Test 846-003-75, CTL-4, Cell 24)

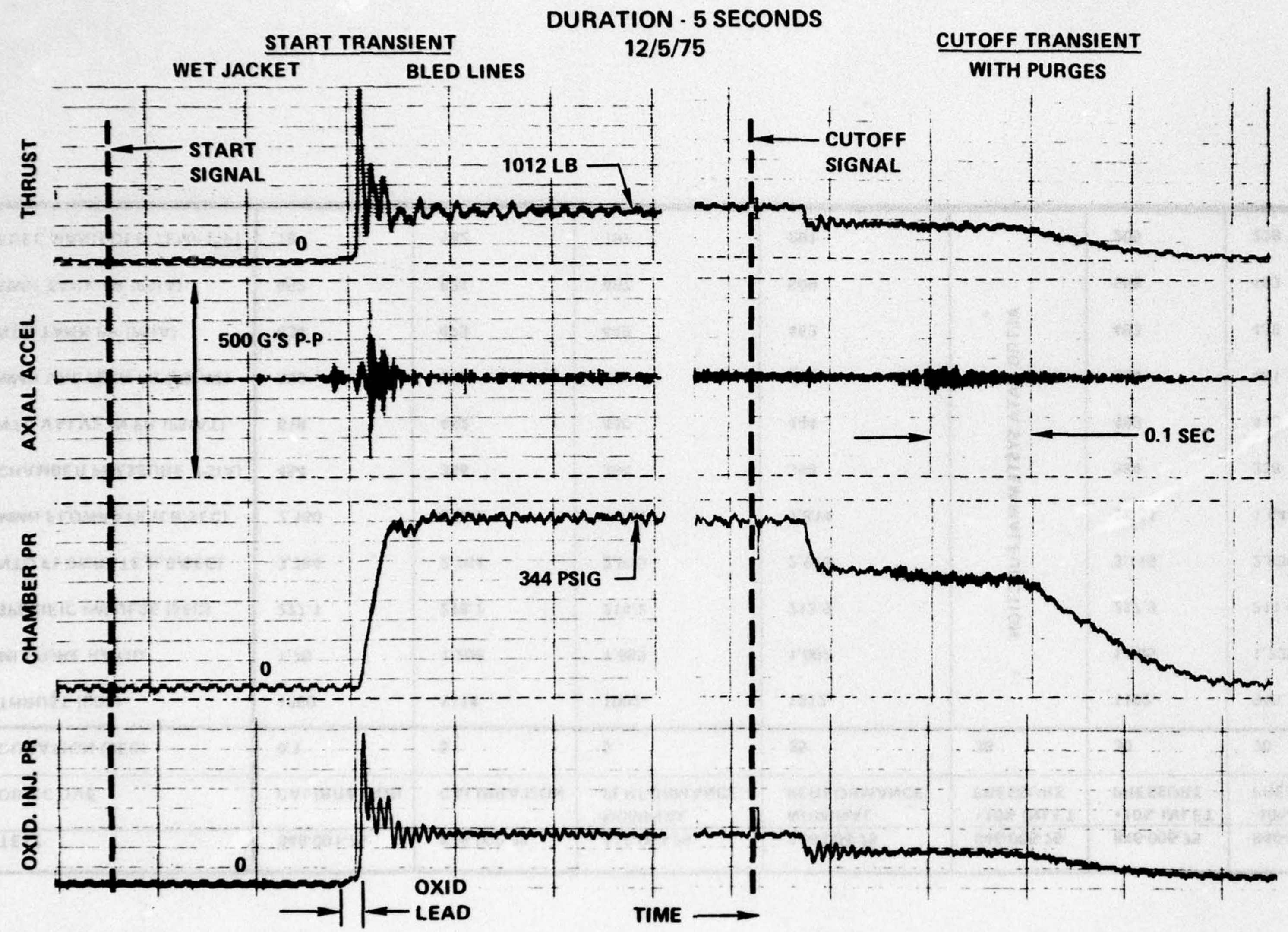


Figure 45. Modified Vernier (-V) Engine (Test 846-004-75, CTL-4, Cell 24)

TABLE 17. MODIFIED VERNIER ENGINE (-V) SITE DATA

TEST	846-001-75	846-002-75	846-003-75	846-004-75	846-005-75	846-006-75	846-007-75
OBJECTIVE	CALIBRATION	CALIBRATION	NOMINAL PERFORMANCE	NOMINAL PERFORMANCE	+10% INLET PRESSURE	+10% INLET PRESSURE	-10% INLET PRESSURE
DURATION (SEC)	0.1	5	5	25	30	30	30
THRUST (LBS)	1350	1114	1002	1012	ASTRO DATA SYSTEM MALFUNCTION	1102	945.7
MIXTURE RATIO	1.75	1.206	1.655	1.607		1.605	1.725
SPECIFIC IMPULSE (SEC)	227.1	218.7	214.2	213.9		217.9	211.5
NTO FLOWRATE (LB/SEC)	3.784	2.784	2.915	2.916		3.115	2.830
MMH FLOWRATE (LB/SEC)	2.160	2.308	1.761	1.814		1.941	1.640
CHAMBER PRESSURE (PSIA)	454	386	354	358		384	338
NTO VALVE IN PR (PSIAT)	618	462	440	444		483	419
MMH VALVE IN PR (PSIAT)	639	613	495	506		554	461
NTO TANK PR (PSIA)	634	473	449	453		493	428
MMH TANK PR (PSIA)	652	631	497	509		558	463
FUEL MANIFOLD TEMP (^{o}F)	78	182	197	201		205	228

TABLE 17. (Concluded)

TEST	846-008-75	846-009-75	846-010-75	846-011-75	846-012-75	846-013-75	846-014-75
OBJECTIVE	+10% MIX. RATIO	-10% MIX. RATIO	NOMINAL	NOMINAL	NOMINAL	NOMINAL	NOMINAL
DURATION (SEC)	10	10	5	5	5	5	5
THRUST (LBS)	1012	1020	1020	1022	1009	1013	1013
MIXTURE RATIO	1.820	1.441	1.492	1.514	1.660	1.642	1.644
SPECIFIC IMPULSE (SEC)	213.8	214.6	215.3	214.6	213.6	215.3	214.9
NTO FLOWRATE (LB/SEC)	3.054	2.805	2.837	2.869	2.949	2.923	2.930
MMH FLOWRATE (LB/SEC)	1.678	1.946	1.902	1.895	1.776	1.780	1.782
CHAMBER PRESSURE (PSIA)	358	361	360	361	358	357	357
NTO VALVE IN PR (PSIAT)	452	440	441	444	446	443	444
MMH VALVE IN PR (PSIAT)	488	530	523	524	503	502	503
NTO TANK PR (PSIA)	464	448	450	454	456	452	454
MMH TANK PR (PSIA)	490	535	527	529	506	505	506
FUEL MANIFOLD TEMP (^{o}F)	244	210	214	220	235	236	235

A total of 14 starts and 170 seconds of mainstage time was accumulated on the -V assembly. The -V assembly was ultimately packaged and delivered to AFRPL.

The -3 vernier engine assembly was tested on 1 December 1976 with two 5-second tests and one 30-second test to demonstrate hardware durability and performance repeatability (Tables 18 and 19). This engine was the same configuration as the -V designation. No difficulties were experienced during this test series. This engine assembly was retained at Rocketdyne for installation in TEM-3.

TABLE 18. MODIFIED VERNIER ENGINE (-3) SITE DATA

TEST	846-001-76	846-002-76	846-003-76
OBJECTIVE	CALIBRATION	NOMINAL PERFORMANCE	-10% INLET PRESSURE
THRUST (LBS)	1008	1019	927.6
MIXTURE RATIO	1.539	1.610	1.576
SPECIFIC IMPULSE (SEC)	215.9	216.4	213.3
NTO FLOWRATE (LB/SEC)	2.381	2.905	2.660
MMH FLOWRATE (LB/SEC)	1.840	1.804	1.6
CHAMBER PRESSURE (PSIA)	357	360	332
NTO VALVE IN PR (PSIAT)	444	450	407
MMH VALVE IN PR (PSIAT)	502	499	453
NTO TANK PR (PSIA)	452	460	414
MMH TANK PR (PSIA)	506	503	455

TABLE 19. MODIFIED VERNIER ENGINE (-3) TEST MATRIX

TEST NO.	TEST DATE	TEST DURATION	OBJECTIVES	RESULTS
846-001-76	1/12/76	5.0 SEC	CALIBRATION TEST FOR REA ΔP DATA	SATISFACTORY TEST. SMOOTH START - 30 MS OXIDIZER LEAD, DRY JACKET START. SMOOTH CUTOFF WITH PURGES ON AT SHUTDOWN.
846-002-76	1/12/76	5.0 SEC	PERFORMANCE TEST	SATISFACTORY TEST. SMOOTH START - 25 MS OXIDIZER LEAD. SMOOTH SHUTDOWN WITH PURGES.
846-003-76	1/12/76	30.0 SEC	PERFORMANCE GAIN TEST - 90% OF NOMINAL INLET PRESSURES (REPEAT OF TEST 846-007-75 ON -V ENGINE)	SATISFACTORY TEST. SMOOTH START - 30 MS OXIDIZER LEAD. SMOOTH SHUTDOWN WITH PURGES.

TASK III. FUNCTIONAL VERIFICATION

Functional verification testing was conducted on the three deliverable target engine systems (TEM-1, -2, and -3) at CTL-4, test cell 24, Santa Susana Field Laboratory (Figure 46). In addition to the cold-flow and hot-fire tests, refurbishment and checkouts of the two propellant tanking units were conducted.

TARGET ENGINE SYSTEM (TES) TESTING

Cold-Flow Tests

Each target engine system was flow calibrated with Freon solvent to generate feed system pressure drop data. These data were required prior to hot fire to properly size propellant feed system orificing and establish a pressure regulator setting.

The flow calibration were conducted in such a manner as to simulate hot-fire conditions as much as possible. In this regard, burst diaphragms were ruptured in a simulated pressurization test and each propellant feed leg was to be flowed separately at various flowrates and with several orifice sizes. The test configuration for the oxidizer-side calibration is shown in Figure 47. This setup was similar to that used for the fuel subsystem except that fuel lines were physically removed to prevent flow through the fuel subsystem during the oxidizer tests. Instrumentation for the calibration tests is shown in Table 20.

The cold-flow testing conducted had the advantage of repeating a calibration of the RS-14 Rocket Engine and thus generated comparative data from another test setup. Another advantage of the cold-flow tests was that each flow leg, using actual hardware, could be calibrated under back-pressure conditions, including a verification of the REA ΔP, thus ensuring maximum validity of the generated data.

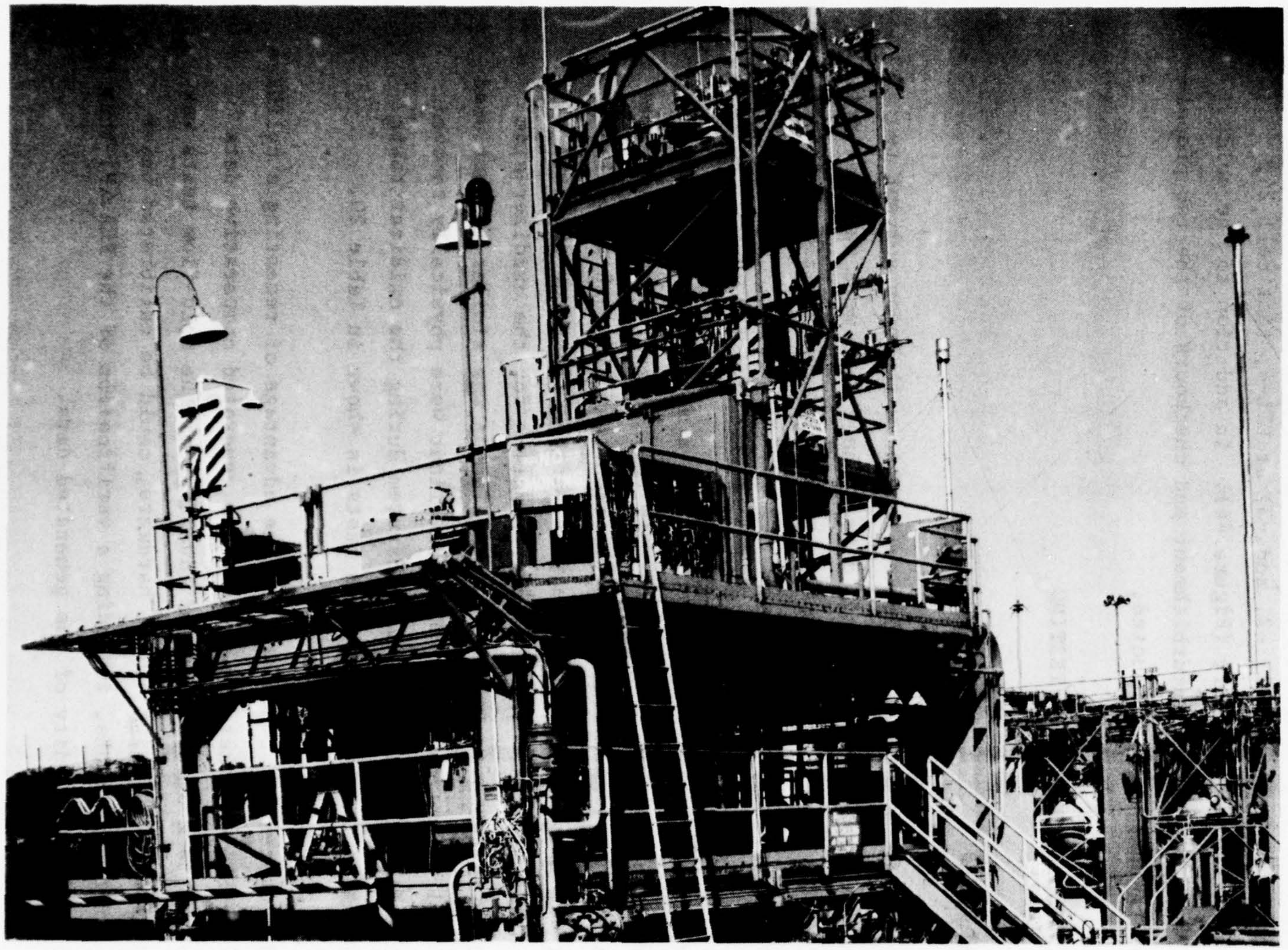


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Figure 46. Components Test Laboratory 4 (CTL-4, Cell 24)

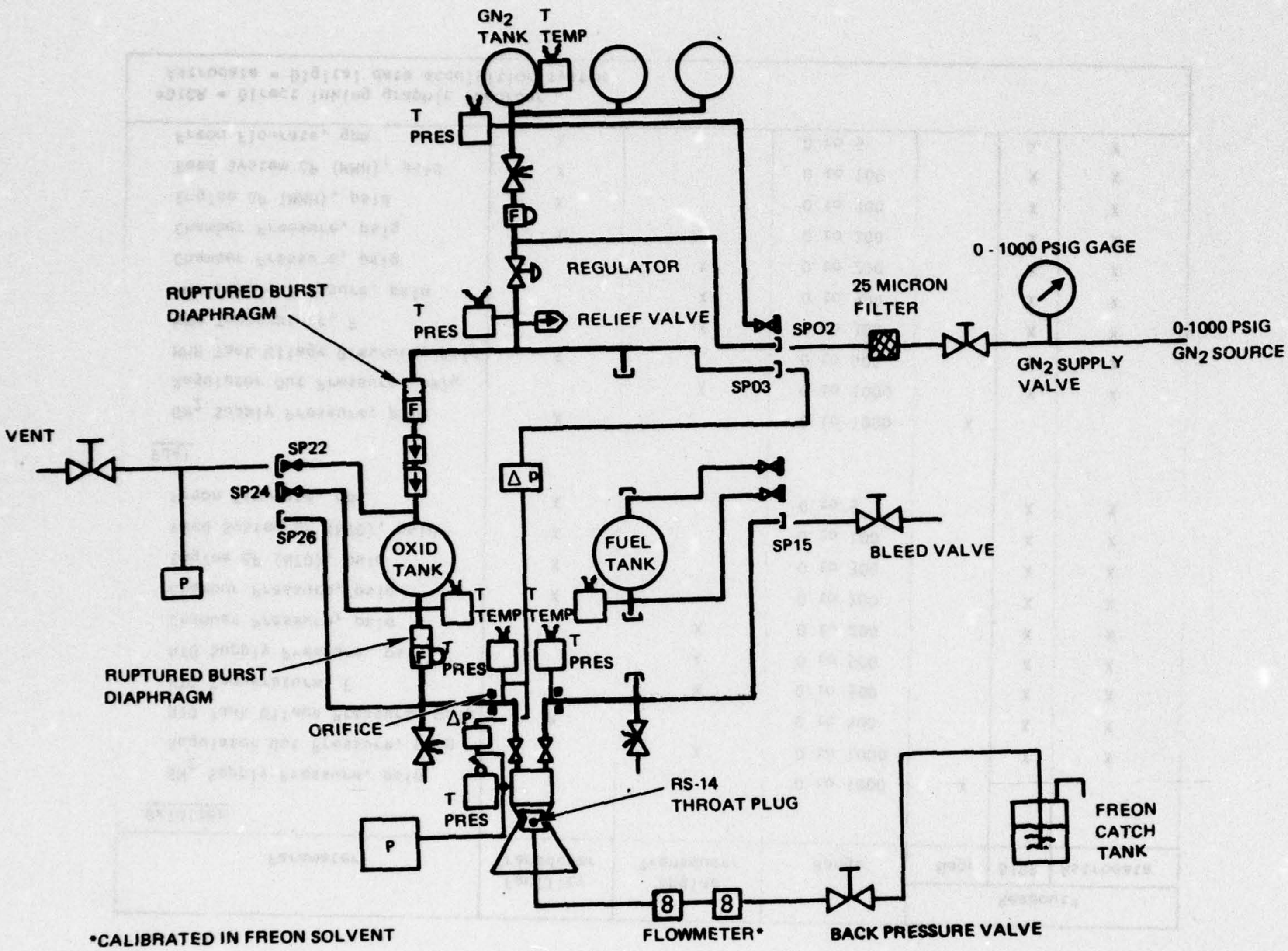


Figure 47. Oxidizer System Cold-Flow Testing Schematic

TABLE 20. TARGET ENGINE SYSTEM COLD-FLOW INSTRUMENTATION

Parameter	Facility Transducer	Engine Transducer	Range	Readout*		
				Gage	DIGR	Astrodata
Oxidizer						
GN_2 Supply Pressure, psig	X		0 to 1000	X		
Regulator Out Pressure, psig		X	0 to 1000		X	X
NTO Tank Ullage Pressure, psig	X		0 to 400		X	X
NTO Temperature, F		X	0 to 300		X	X
NTO Supply Pressure, psig		X	0 to 500		X	X
Chamber Pressure, psig		X	0 to 200		X	X
Chamber Pressure, psig	X		0 to 200		X	X
Engine ΔP (NTO), psid	X		0 to 300		X	X
Feed System ΔP (NTO), psid	X		0 to 100		X	X
Freon Flowrate, gpm	X		0 to 5		X	X
Fuel						
GN_2 Supply Pressure, psig	X		0 to 1000	X		
Regulator Out Pressure, psig		X	0 to 1000		X	X
MMH Tank Ullage Pressure, psig	X		0 to 400		X	X
MMH Temperature, F		X	0 to 300		X	X
MMH Supply Pressure, psig		X	0 to 500		X	X
Chamber Pressure, psig		X	0 to 200		X	X
Chamber Pressure, psig	X		0 to 200		X	X
Engine ΔP (MMH), psid	X		0 to 300		X	X
Feed System ΔP (MMH), psid	X		0 to 100		X	X
Freon Flowrate, gpm	X		0 to 5		X	X

*DIGR = Direct inking graphic recorder
Astrodata = Digital data acquisition system

Initial program requirements were to cold-flow test each TES prior to hot fire using a "dummy" thrust chamber to simulate the hydraulic resistances of the flight rocket engine assemblies. The "dummy" thrust chamber was envisioned as having removable orifices, flowmeters, and shutoff valves in each propellant feed leg.

With the availability of RS-14 and Atlas vernier engine throat plugs capable of flowing the required freon flowrates, it was considered expeditious to cold flow each system with the deliverable rocket engine. The following savings were achieved over the original plan with this decision:

1. The "dummy" assembly was not required.
2. The TES could be cold flowed in the hot-fire test stand, thereby eliminating another test facility with attendant setups and additional instrumentation and control requirements.

Hot-Fire Tests

Test objectives of the hot-fire portion of the testing were:

1. Demonstrate function and durability of actual flight hardware, including the flight instrumentation transducers, during a simulated mission duty cycle
2. Demonstrate performance criteria--chamber pressure and mixture ratio limits
3. Demonstrate adequacy of the tanking and decontamination procedures using the propellant loading carts (GFP)
4. Demonstrate adequacy of the GN_2 charging procedure
5. Generate engineering data regarding:
   - Pressurization transient
   - Propellant dump transient

- System dynamic response for the engine start/cutoff
- Transients
- Duty cycle burns
- Component flow/ΔP information

The target engine systems tested are shown schematically in Fig. 48 and and 49. Each system was calibrated and test fired to demonstrate its operational capabilities in accordance with the following test plan. The efforts in support of the actual test firing of the system were minimized through full utilization of cold-flow precalibration techniques. A process flow chart used at the test site is presented in Fig. 50.

Following the demonstration testing of the modified vernier engines, the CTL-4, cell 24 facility was modified to accept the target engine system. A new supporting structure was installed to accept the base interface of the target engine structure. Facility servicing connections were installed for use after the utility of the propellant servicing carts was demonstrated. The connections provided for filling and draining of the referee propellants as well as the hot-firing propellants. A GN_2 supply was connected, as well as instrumentation lines for facility items and lines for the discharge of the propellant dump valves. Following installation and leak test, the facility control system was verified by checkout operation as described later.

TEM-1 TESTING

Significant dates during the assembly, test and delivery of TEM-1 are as follows:

	1976
Structure received at Rocketdyne	22 March
Assembly completed	3 May
System pressurization test accomplished	27 May
Cold-flow calibrations completed	4 June

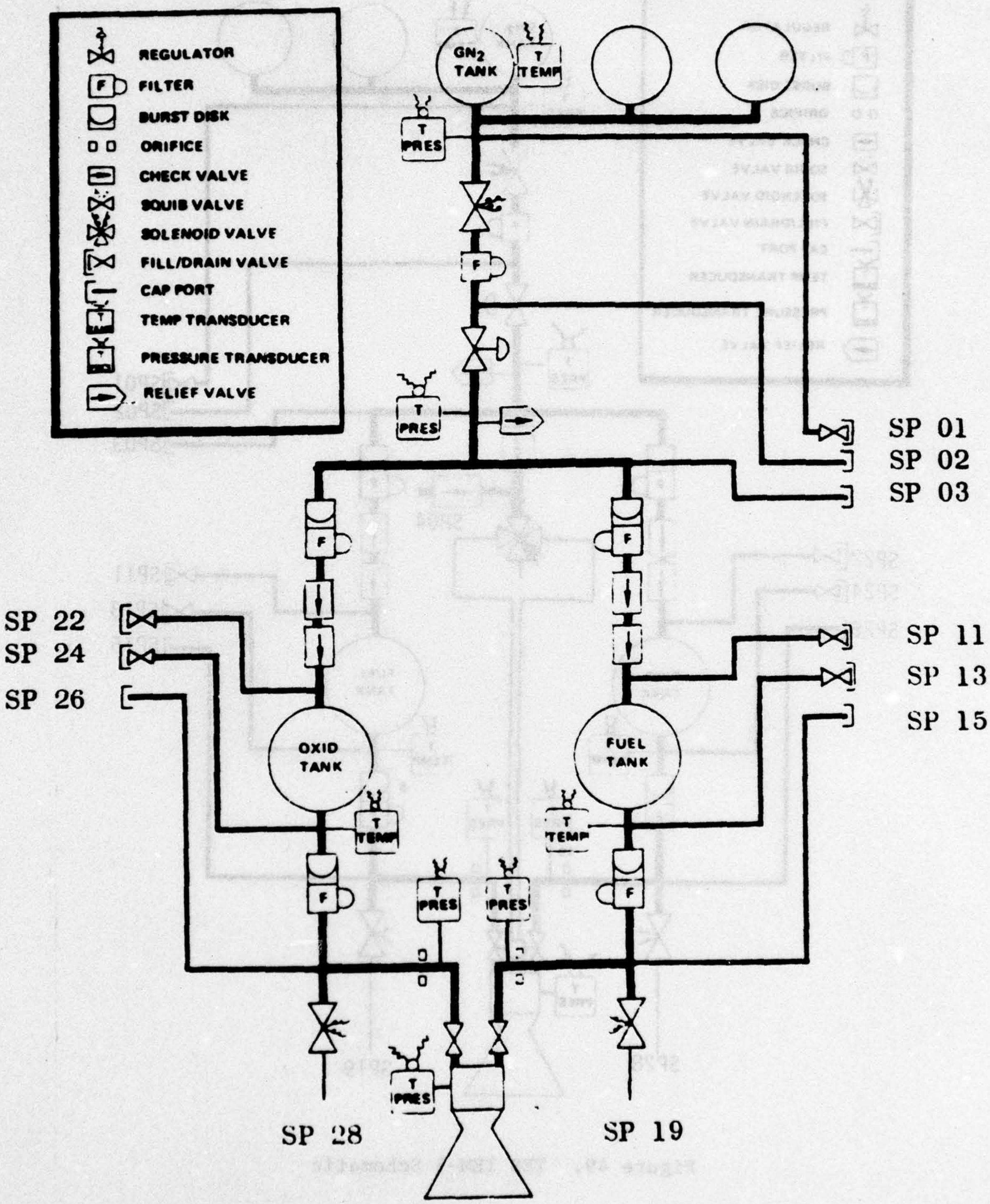


Figure 48. TES TEM-1 and -2 Schematic

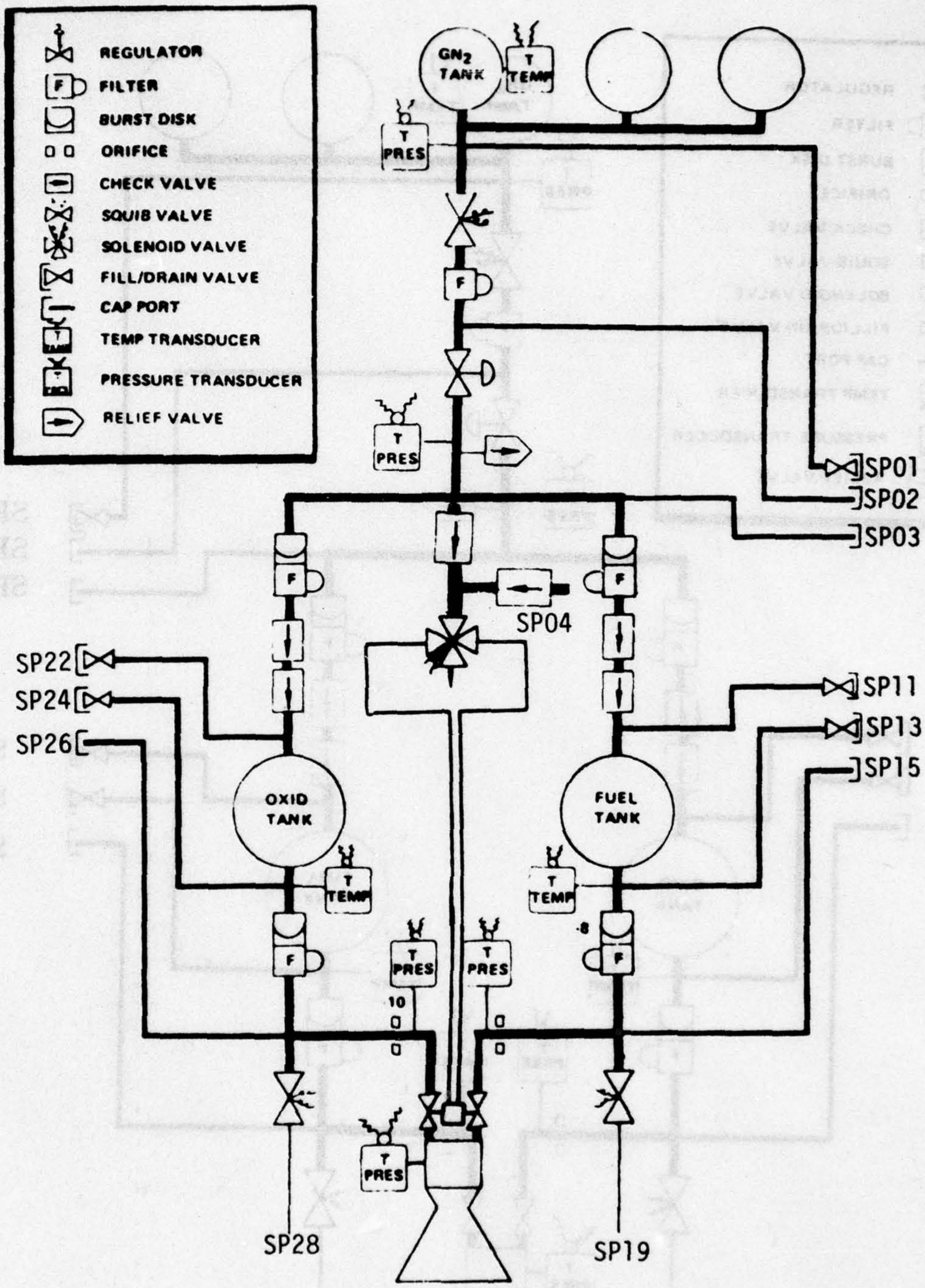


Figure 49. TES TEM-3 Schematic

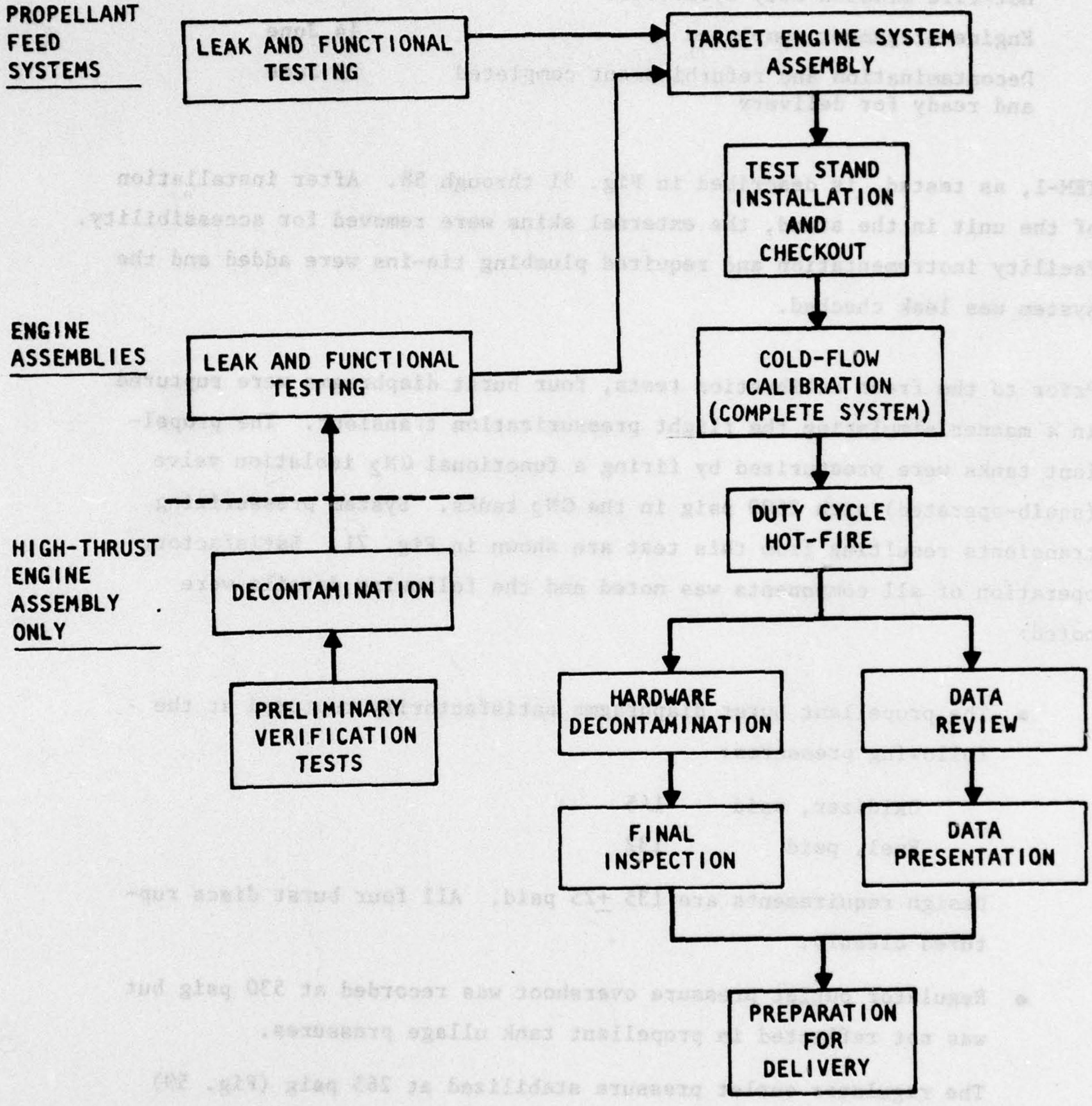


Figure 50. TES Functional Verification Process Flow

Module tanked with propellants	10 June
Hot-fire mission duty cycle test	11 June
Engine alignment completed	14 June
Decontamination and refurbishment completed and ready for delivery	23 June

TEM-1, as tested, is described in Fig. 51 through 58. After installation of the unit in the stand, the external skins were removed for accessibility. Facility instrumentation and required plumbing tie-ins were added and the system was leak checked.

Prior to the freon calibration tests, four burst diaphragms were ruptured in a manner simulating the flight pressurization transient. The propellant tanks were pressurized by firing a functional GN_2 isolation valve (squib-operated) with 2600 psig in the GN_2 tanks. System pressurizing transients resulting from this test are shown in Fig. 71. Satisfactory operation of all components was noted and the following details were noted:

- The propellant burst diaphragms satisfactorily ruptured at the following pressures:

Oxidizer, psid	145
Fuel, psid	132

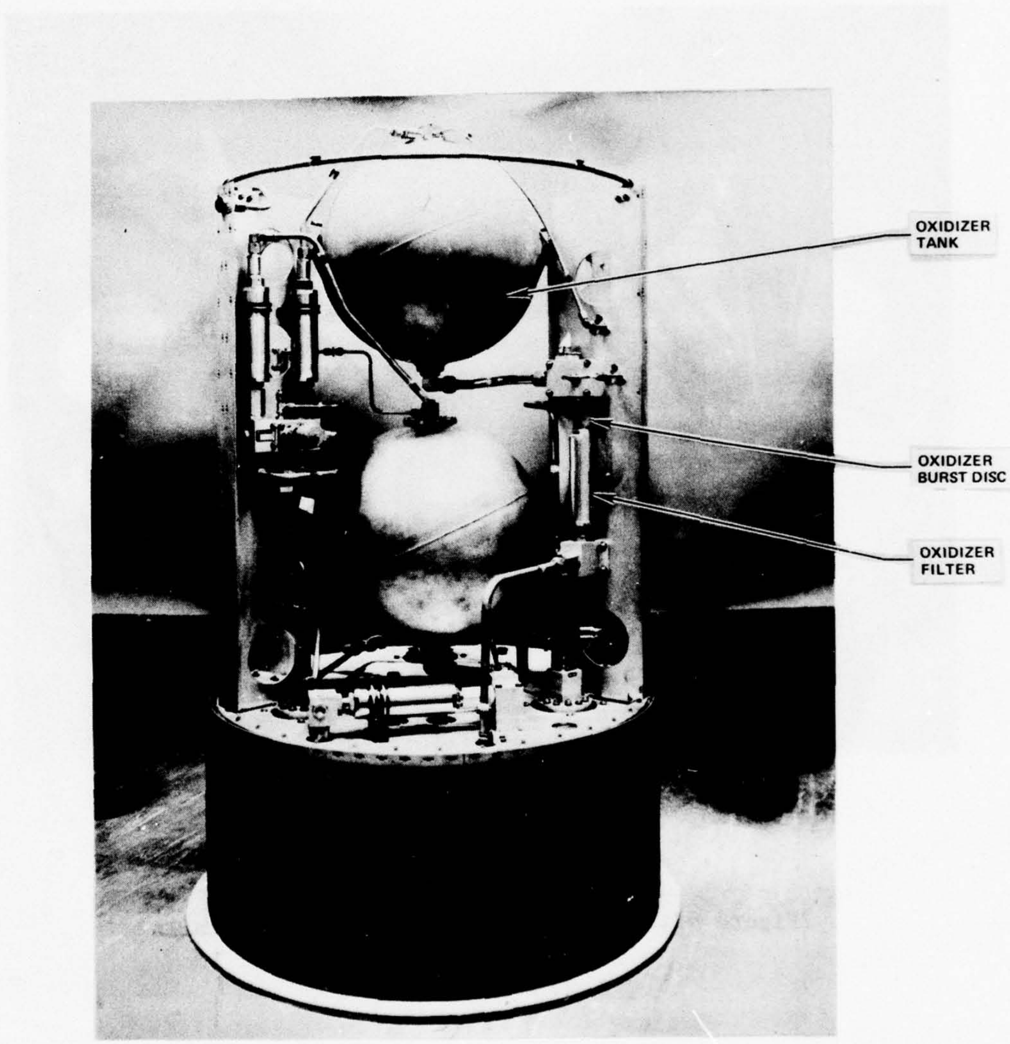
  Design requirements are 135 $\pm$25 psid. All four burst discs ruptured cleanly.

- Regulator outlet pressure overshoot was recorded at 530 psig but was not reflected in propellant tank ullage pressures.

  The regulator outlet pressure stabilized at 265 psig (Fig. 59)

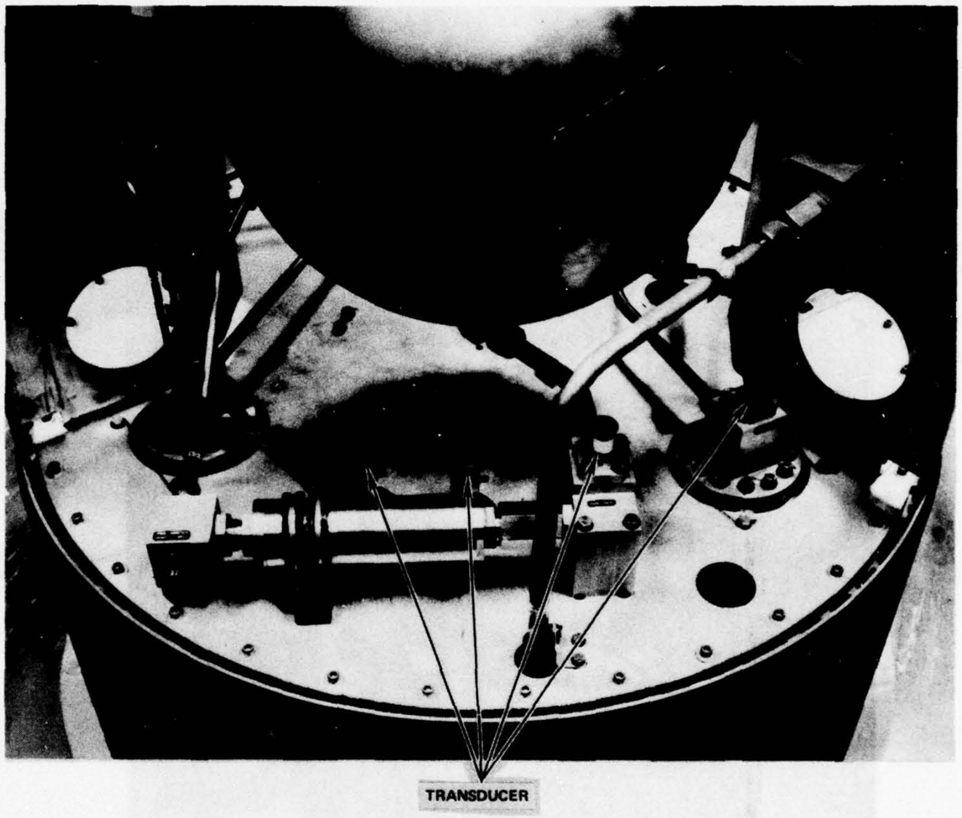
- Time for pressure to stabilize in the propellant tanks was 3.8 seconds (Fig. 59).

The oxidizer subsystem was calibrated with freon solvent. Four orifice sizes (wide open, 0.200, 0.250 and 0.375 inch) were checked at several



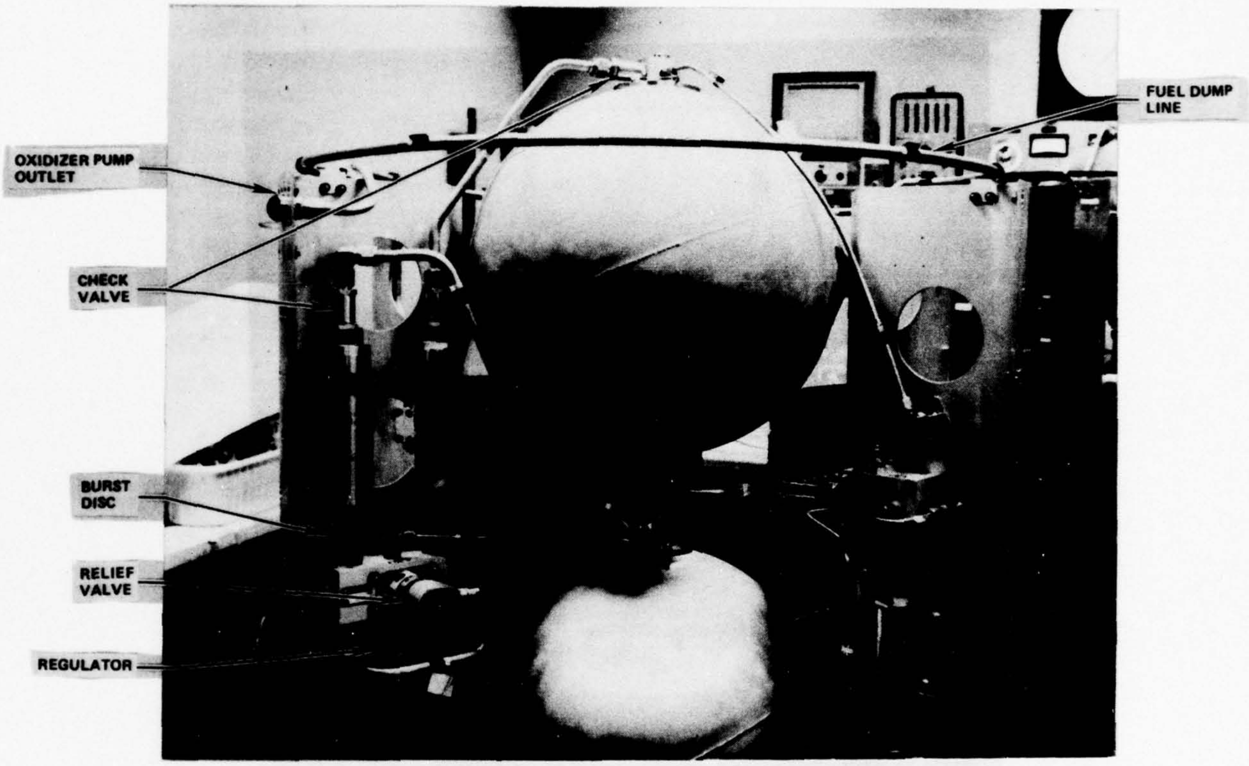
LC279-67

Figure 51. Target Engine System TEM-1



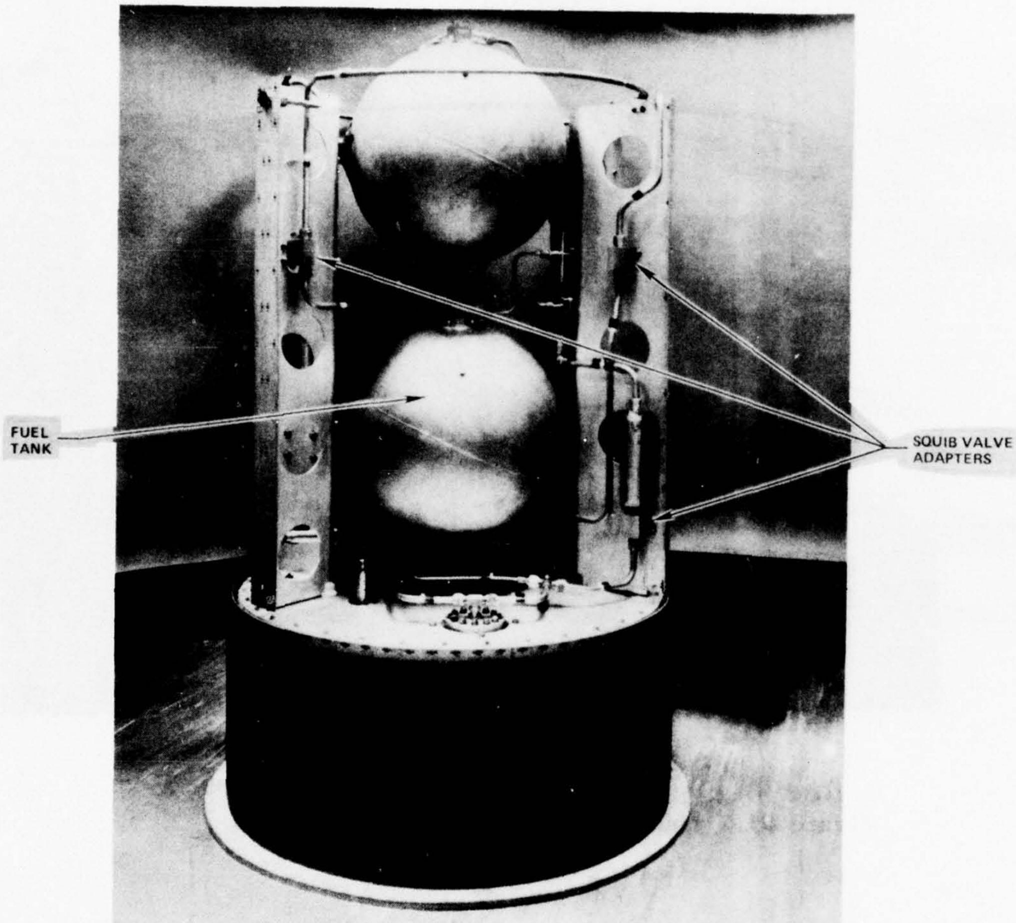
LC279-70

Figure 52. Target Engine System TEM-1 Details



LC279-69

Figure 53. Target Engine System TEM-1 Details



LC279-66

Figure 54. Target Engine System TEM-1

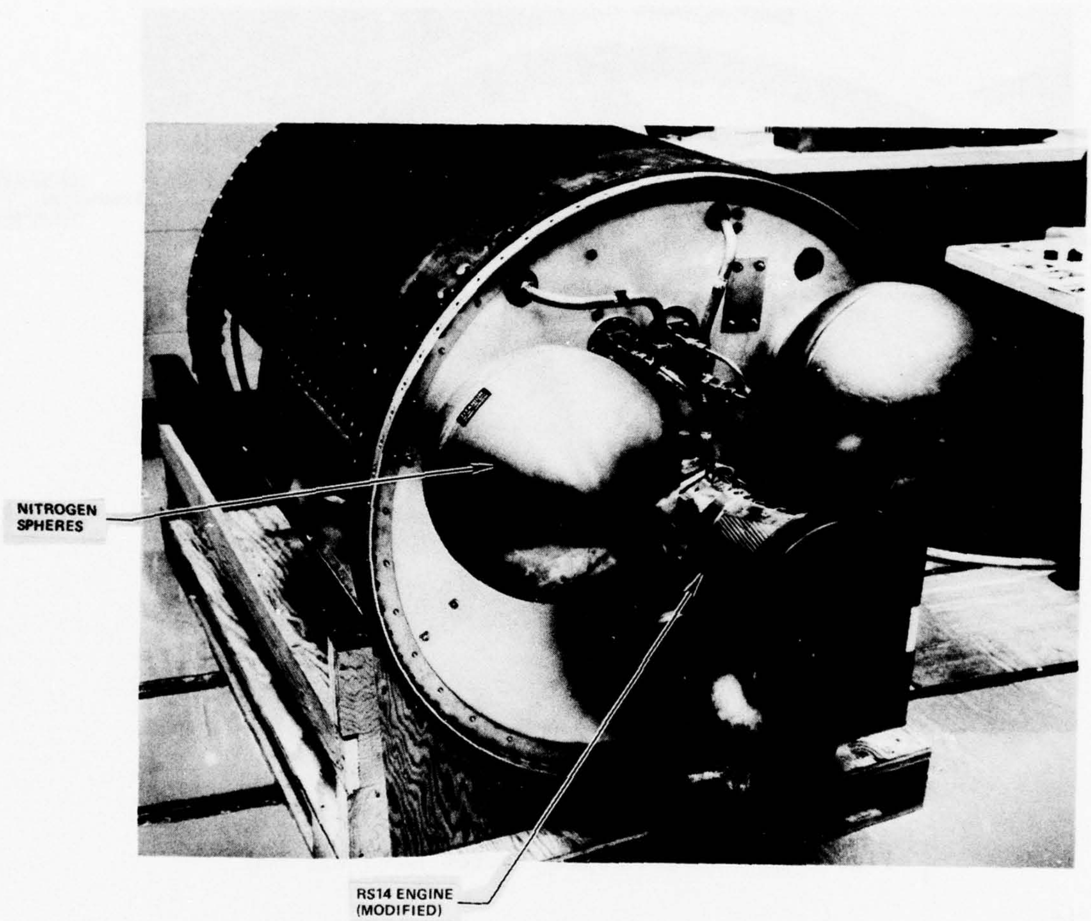


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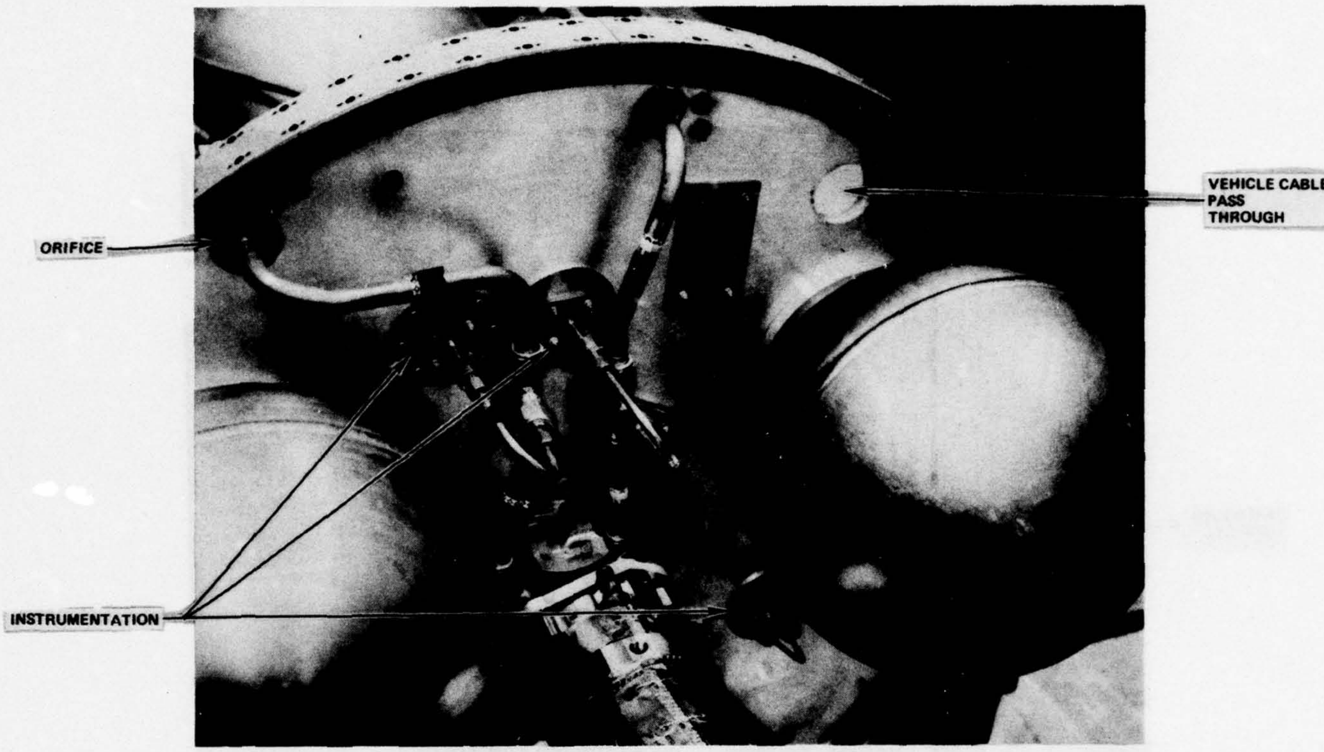
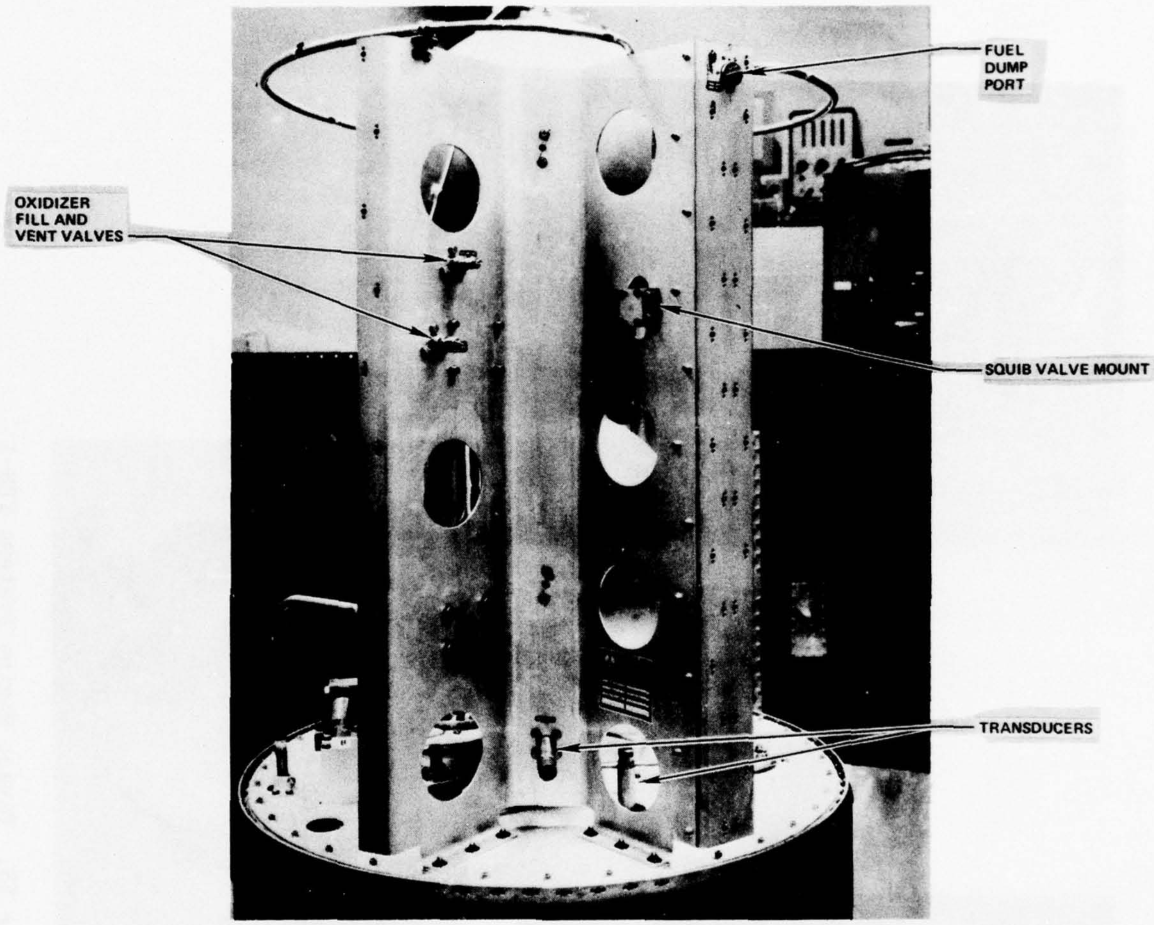
Figure 55. Target Engine System TEM-1 Aft End View



LC279-71

Figure 56. Target Engine System TEM-1 Aft End



LC279-65

Figure 57. Target Engine System TEM-1 Typical Service Connections

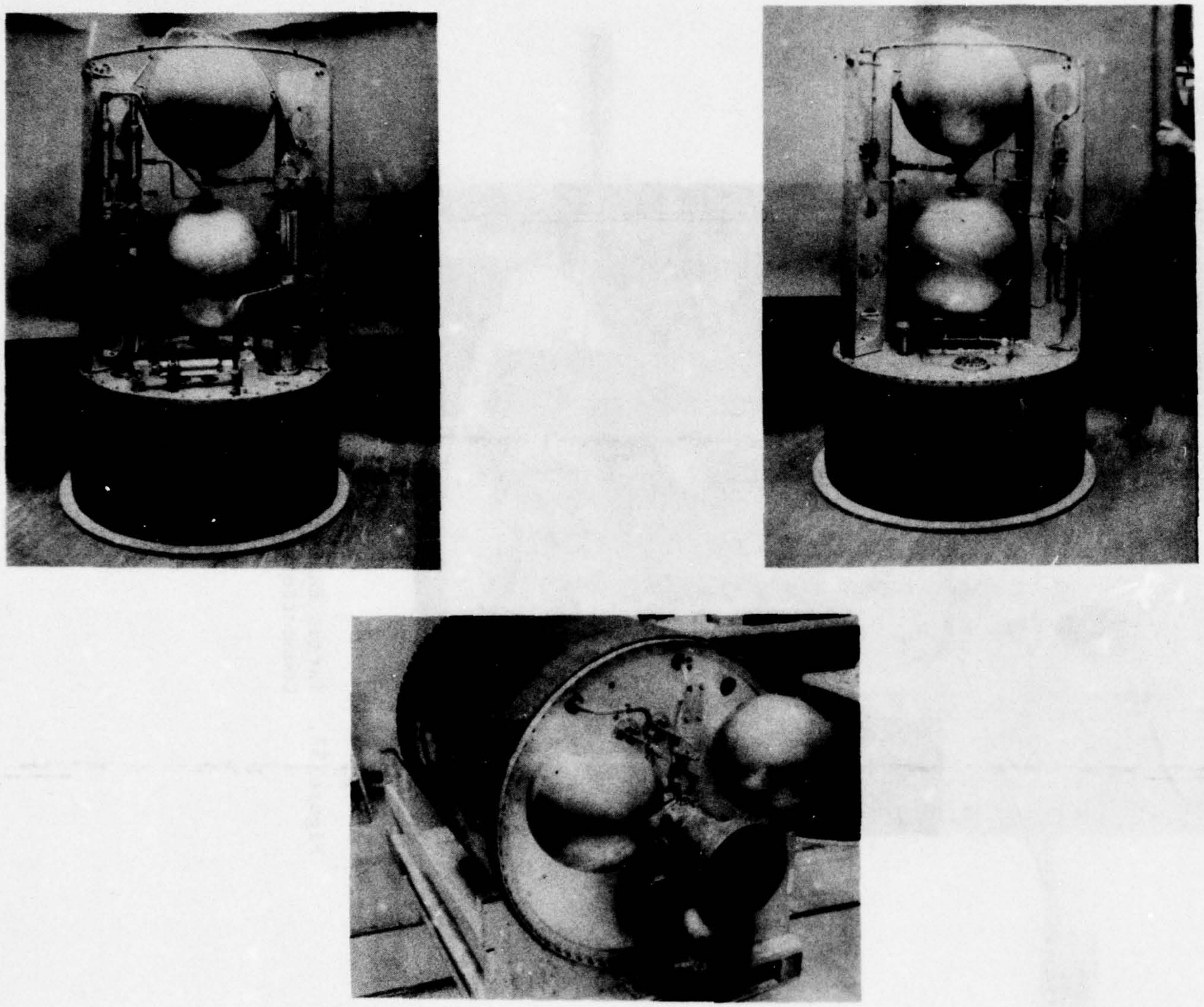


Figure 58. Target Engine Systems TEM-1

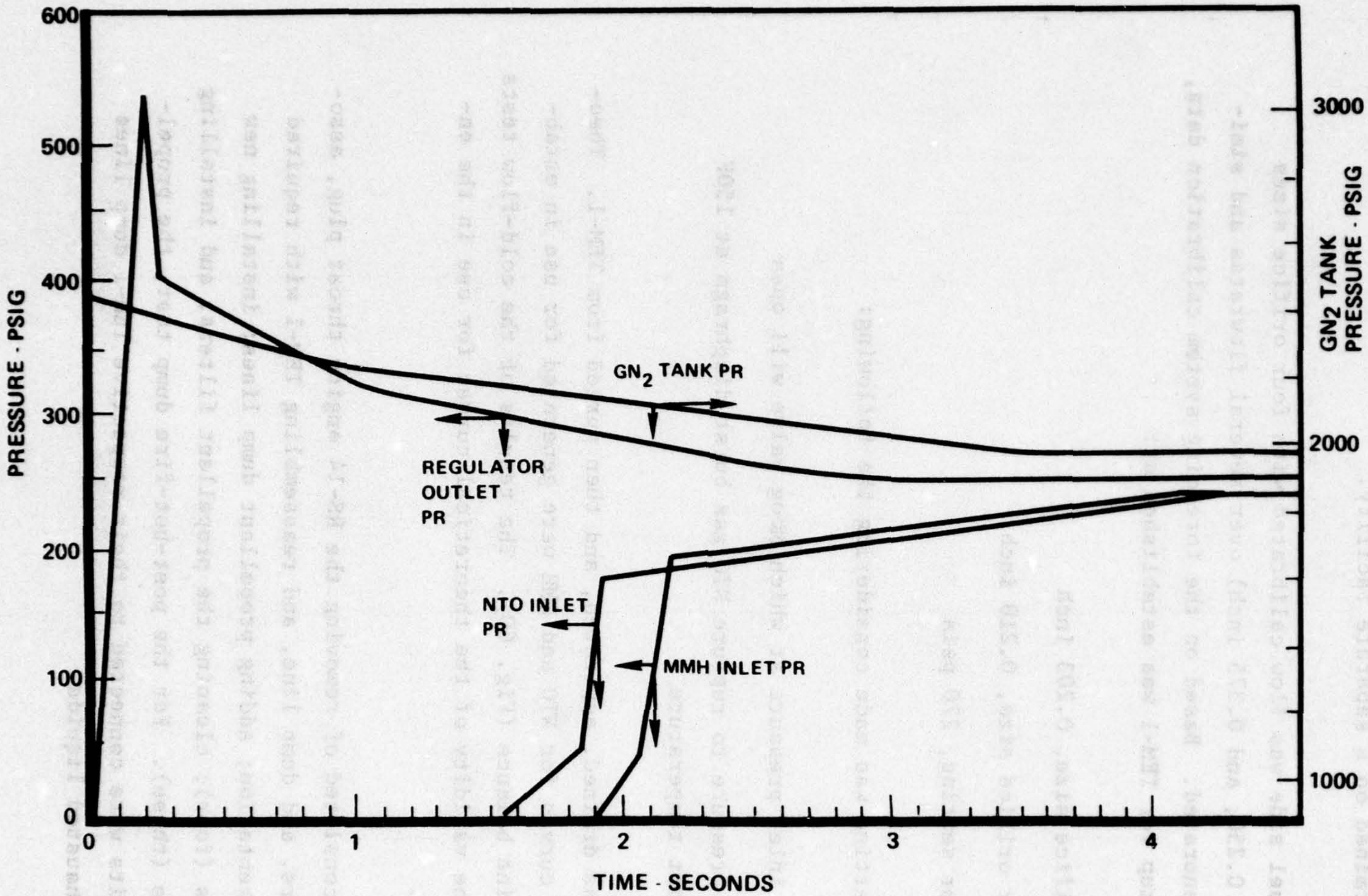


Figure 59. Pressurization Transient TEM-1 Hot Fire

flowrates, generating hydraulic resistance data for the oxidizer feed system portion of TEM-1 as well as corroborating the RS-14 engine data previously determined on a separate facility.

Likewise, the fuel side was flow calibrated with four orifice sizes (0.1875, 0.200, 0.250, and 0.375 inch) over several flowrates and similar data were generated. Based on the foregoing system calibration data, the hot-fire setup for TEM-1 was established at:

- Fuel orifice size, 0.203 inch
- Oxidizer orifice size, 0.210 inch
- Regulator setting, 270 psia

The regulator setting was made considering the following:

- Maximum inlet pressure at which Moog valve will open
- Minimum pressure to rupture NTO gas burst diaphragm at 150F propellant temperature

Freon solvent was drained, aspirated, and then purged from TEM-1. Theoretical orifice curves for NTO and MMH were generated for use in establishing the engine balance (Fig. 60). The results of the cold-flow tests substantiated the validity of the theoretical curves for use in the engine math model.

Hot-fire setup consisted of removing the RS-14 engine throat plug, associated flowmeters, and dump line, and reassembling TEM-1 with required facility instrumentation; adding propellant dump lines; installing new burst diaphragms (four); cleaning the propellant filters; and installing new squib valves (three). For the post-hot-fire dump test, the propellant loading units were connected to their respective TEM-1 dump lines to catch the exhausted liquids.

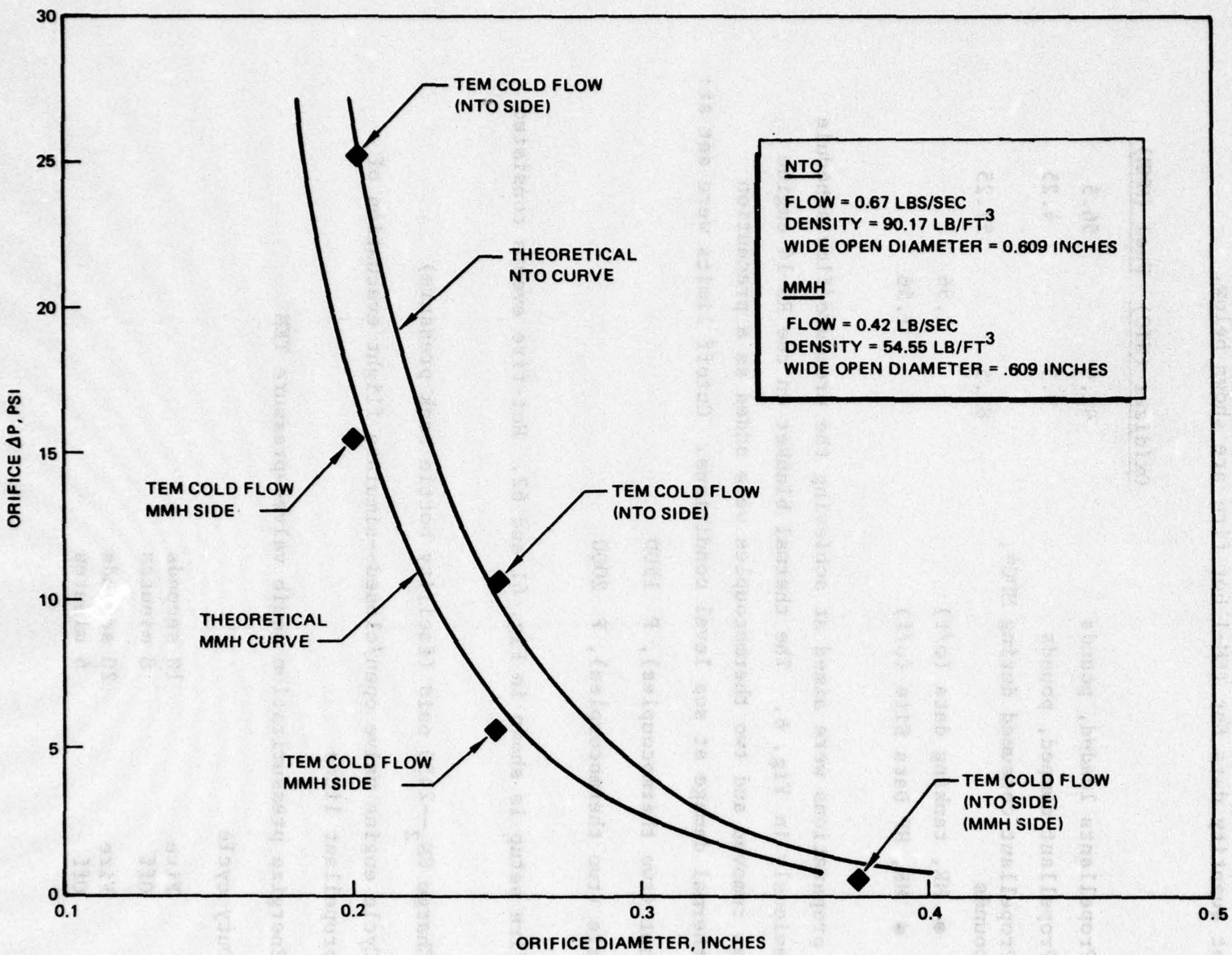


Figure 60. NTO and MMH Orifice ΔP

Propellant quantity data for TEM-1 hot fire are shown below.

	Oxidizer (NTO)	Fuel (MMH)
• Propellants loaded, pounds	91.0	56.5
• Propellant dumped, pounds	9.5	4.25
• Propellant consumed during MDC*, pounds	81.5	52.25
• MR, tanking data (o/f)	1.56	
• MR, HF Data Site (o/f)	1.56	

Hot-fire preparations were aimed at achieving the pressure/flow schedule shown previously in Fig. 6. The thermal blanket on the RS-14 engine nozzle was removed and two thermocouples were added as a precaution against thermal damage at sea level conditions. Cutoff limits were set at:

Throat (two thermocouples), F 1500

Nozzle (two thermocouples), F 2000

The hot-fire setup is shown in Fig. 61 and 62. Hot-fire events consisted of:

- Charge GN_2--2450 psid (facility bottle bank pressure)
- Cycle engine valve open/closed--simulate flight evacuation of propellant lines
- Energize pressurization squib valve--pressure TEM
- Duty cycle

Fire	10 seconds
Off	8 minutes
Fire	20 seconds
Off	6 minutes

*Mission Duty Cycle: 6 burns, 119.94 seconds total duration

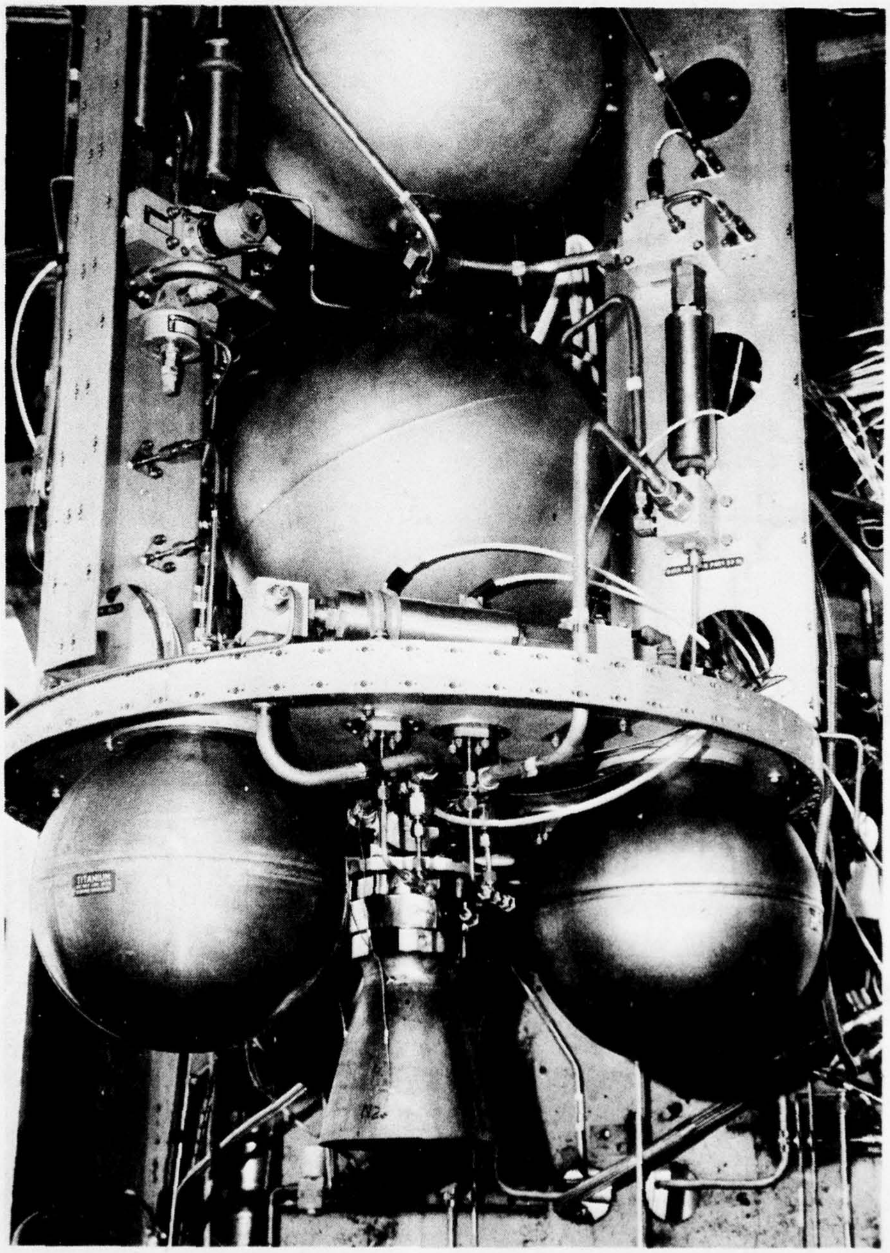


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Figure 61. Hot-Fire Test Setup

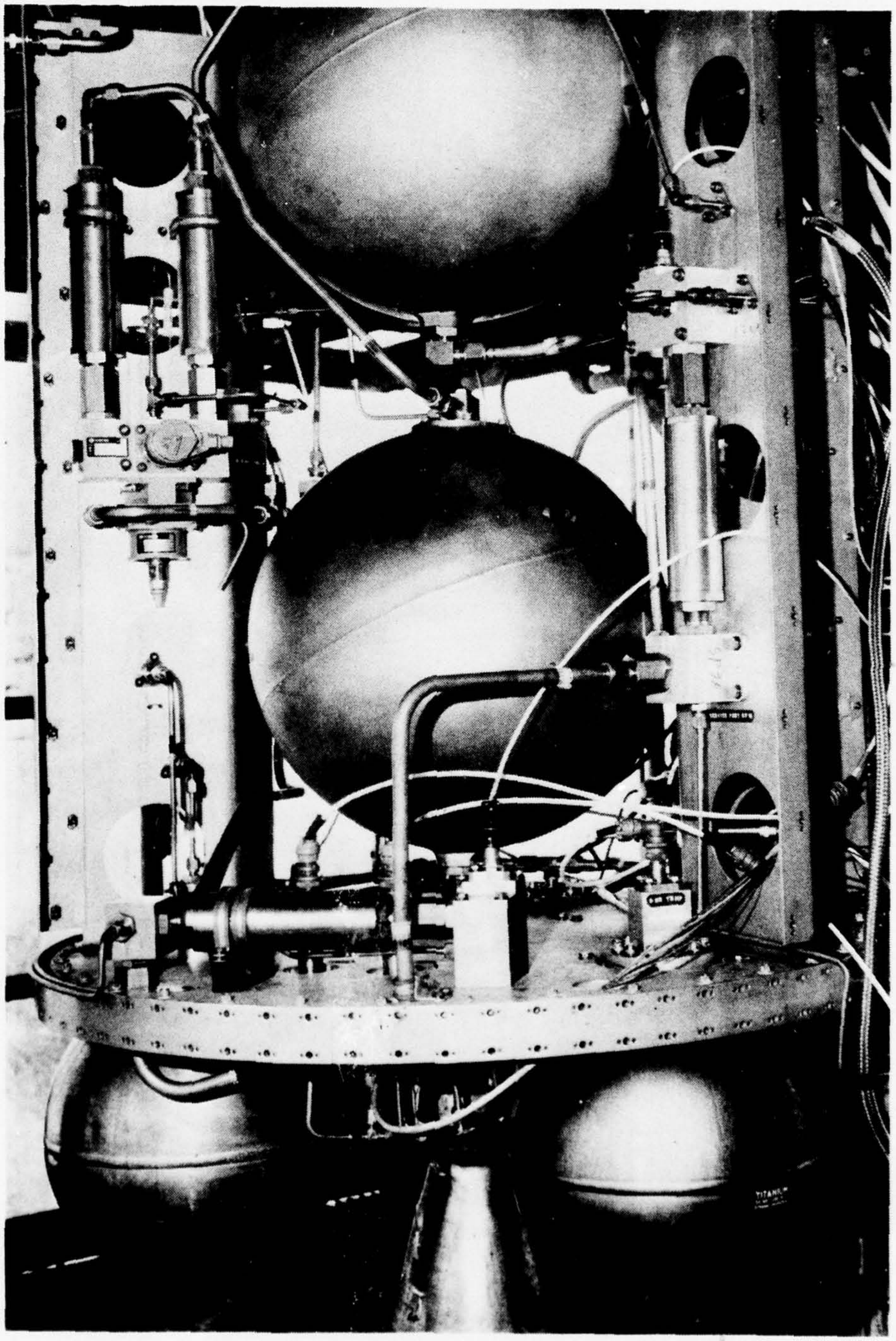

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Figure 62. Hot-Fire Test Setup

Fire	20 seconds
Off	6 minutes
Fire	25 seconds
Off	1 minute
Fire	15 seconds
Off	3 minutes
Fire	29 seconds

- Dump residual propellants and pressurant--simulate post-flight hot-fire propellant dump

Hot fire testing was entirely successful in that no hardware difficulties were experienced. Performance was as predicted (see section on performance for results), and tanking equipment and procedure appeared satisfactory. All test objectives were met in that this flight system demonstrated the capability to meet flight requirements. Two minor component problems were noted:

1. The burst diaphragm assembly was found lacking an internal seal and would leak at low pressure. The addition of an aluminum seal in each assembly prevented further leakage.
2. The relief valve (pilot operated) leaked a small amount of GN_2 overboard during the system pressurization transient. It was concluded that the leakage was not significant.
3. Propellant dump transient did not simulate flight conditions and was too long in duration (dump lines had too much back pressure). This test was repeated in TEM-2 testing.

Posttest hardware preparations for delivery consisted of the following operations:

- Propellant decontamination
  - RS-14 engine removed and decontaminated per production specification RAO-230-289

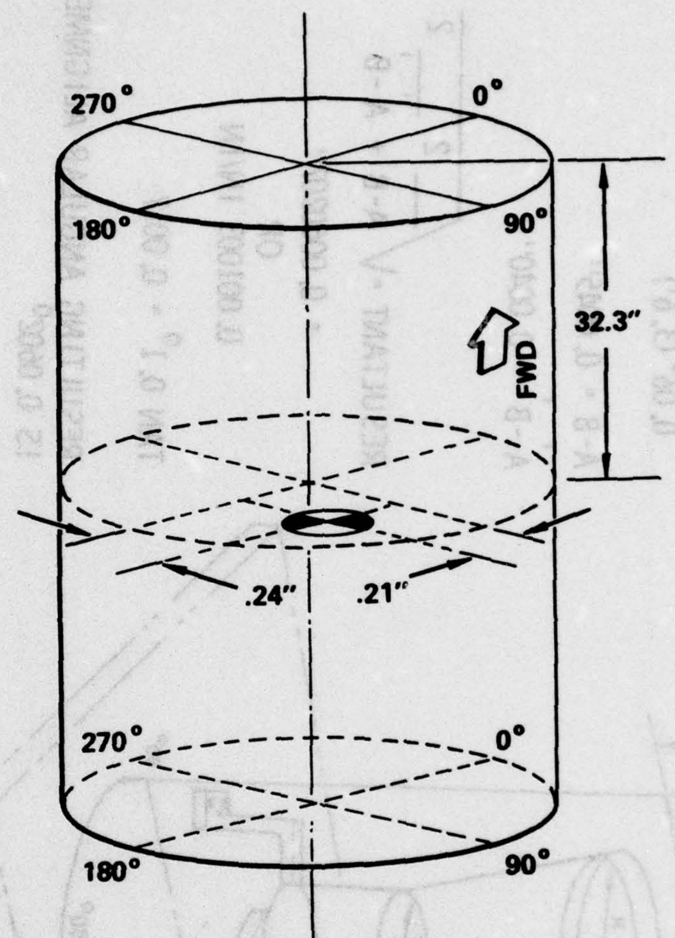
- Fuel feed system flushed with alcohol, purged with GN_2, and vacuum dried
- Oxidizer feed system flushed with freon, purged with GN_2, and vacuum dried
- RS-14 engine thermal blanket reinstalled
- Filter elements cleaned and reassembled
- Expended squibs removed and shipping covers installed over ports
- Burst diaphragms replaced (four)
- GN_2 lines upstream of check valves sniffed for traces of propellants--none noted
- System leak checked
- Skins and doors installed
- Unit packaged for shipment
- Signal conditioner amplifiers for thermocouples installed

Previously, the weight and center of gravity had been determined as shown in Fig. 63. Angular alignment, as shown in Fig. 64 and 16, was determined and found to be acceptable.

TEM-2 TESTING

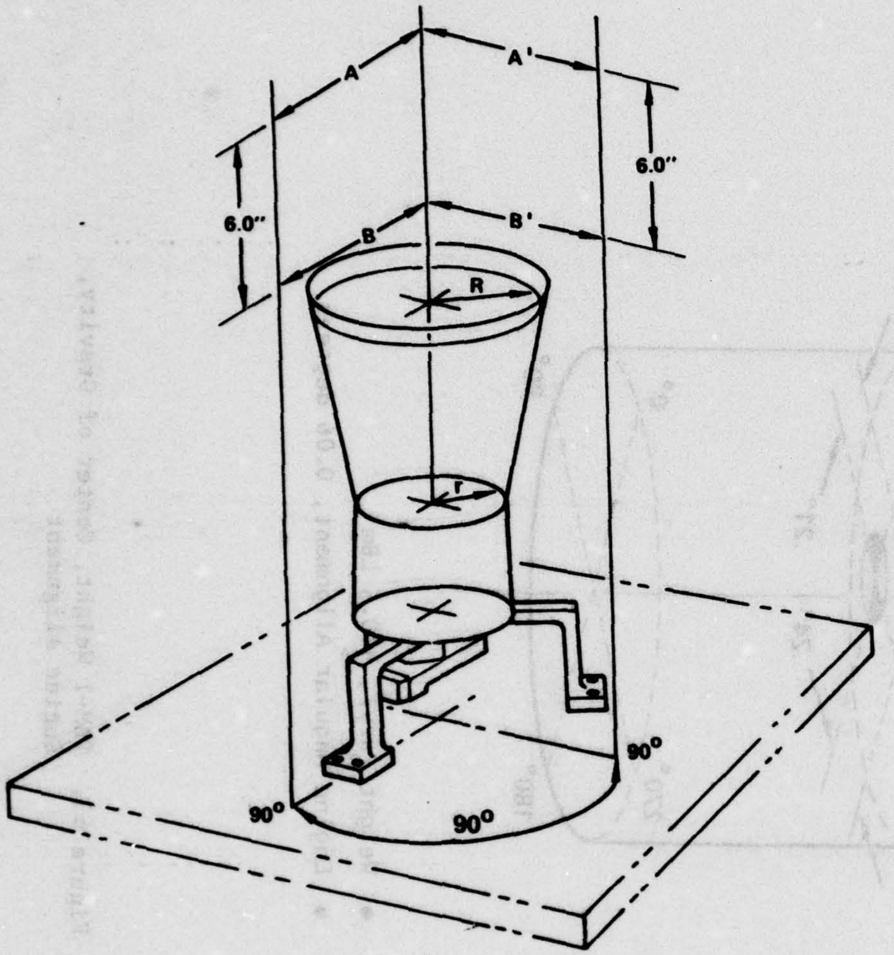
Major historical events in TEM-2 testing are:

	1976
Assembly completed	31 August
Accelerometers added to flight hardware	29 October
System pressurization tests accomplished (with and without relief valve)	2 November
Cold-flow calibrations completed	2 November



- Weight (dry), 480.5 LBm
- Engine Angular Alignment, 0.06 degrees

Figure 63. TEM-1 Weight, Center of Gravity, Engine Alignment



REQUIREMENT

0.1^{0} (6')

MEASUREMENT

0.06^{0} (3.6')

$A-B = 0.0045''$

$A'-B' = 0.0040''$

$$\text{RESULTANT} = \sqrt{\overline{A-B}^{2} + \overline{A'-B'}^{2}}$$

$= 0.0060207''$

OR

0.001003 IN/IN

$\text{TAN } 0.1^{0} = 0.0017$

RESULTING ANGULAR ALIGNMENT IS 0.0602^{0}

Figure 64. TEM-1 Engine Alignment

	1976
Module tanked with propellants	3 November
Hot-fire mission duty cycle test	3 November
Propellant dump test completed (full load simulated)	4 November
Decontamination and refurbishment completed and ready for delivery	5 November

In a cooperative program with the U.S. Army (Area Interceptor), TEM-2 and -3 were equipped with accelerometers at the following locations:

- RS-14 engine, at gimbal bolt (throat)
- Oxidizer tank mount at 180 degrees
- Oxidizer tank mount at 360 degrees
- Oxidizer tank outlet boss
- Hat section aft at 180 degrees
- Hat section aft at 360 degrees
- Fuel tank mount at 360 degrees

The purpose of this instrumentation was to generate actual ground test vibrational data that could be compared to a prediction technique. Results showed good agreement with those determined by the Barrett method. The accelerometer blocks were left on TEM-2 and -3 for use during flights.

Two pressurization system transient tests were conducted to determine the amount of GN_2 dumped overboard through the relief valve. During TEM-1 testing, it was determined that the pilot-operated relief valve opened momentarily during the system pressurization transient.

Freon was tanked to volumes simulating flight propellant loads. With GN_2 tanks at 2500 psig, the GN_2 isolation valve was energized, pressurizing the system. The following was noted:

- **Pressurization Test with Relief Valve**
  - Approximately 1-1/2 pounds of GN_2 unaccounted for
  - Overboard leakage through relief valve confirmed audibly--2 seconds duration (minor effect)
  - Other effects include solubility of GN_2 in propellants, no thermal stabilization of system components, and constant bleeds (two) from regulator (all minor effects)

The relief valve was removed, a special plug was installed in its place, and the above test was repeated:

- **Pressurization Test Without Relief Valve**
  - Approximately 1 pound of GN_2 unaccounted for due to solubility of GN_2 in propellants, no thermal stabilization of system components, and constant bleeds (two) from regulator (all minor effects)

It was concluded that the amount of GN_2 lost overboard was not significant and the targeted quantity would be sufficient to complete the flight mission. An examination of the design of the relief valve (P/N 550084), shows that the internal orificing to the spring side of the poppet is relatively small and that the overall device is designed for essentially a steady state condition.

Freon calibration tests were conducted in a manner similar to TEM-1 except that only one orifice per each flow leg was tested. These data verified that there was no significant hydraulic resistance difference between TEM-1 and -2. TEM-2 was then orificed as follows, based on the detailed data generated with TEM-1:

• Fuel orifice size, inch	0.1870
• Oxid orifice size, inch	0.2115
• Regulator setting, psia	270

TEM-2 hot fire preparations consisted of tanking the following propellants using the propellant loading carts.

Oxidizer, pounds	91.0
Fuel, pounds	56.5

GN_2 was charged to 2500 psig and the engine valve was cycled opened/closed to simulate the flight propellant line evacuation operation. After the system pressurization transient, the following hot-fire duty cycle was accomplished:

Fire	15 seconds
Off	15 minutes
Fire	15 seconds
Off	10 minutes
Fire	20 seconds
Off	5 minutes
Fire	25 seconds
Off	5 minutes
Fire	15 seconds
Off	5 minutes
Fire	29 seconds

No problems were noted during the hot-fire testing. No hardware problems were noted and performance was satisfactory, as expected. No operational difficulties were experienced with the tanking equipment or procedure. A comparison of the flight pressure transducer data with duplicate facility measurements showed excellent agreement (Table 21).

TEM-2 pressure/flow schedule results (Fig. 7) compared very well with TEM-1, indicating excellent system performance repeatability.

After the hot-firing mission-duty cycle, residual propellants were aspirated from the propellant tanks and lines in preparation for an emergency dump test. Propellant tanks and feed systems were filled to overflow with freon (oxidizer) and alcohol (fuel) then off-loaded to

TABLE 21. TES TEM-2 HOT-FIRE PERFORMANCE TEM FACILITY INSTRUMENTATION COMPARISON (TEST 018)

Parameter	TEM	Facility
Chamber Pressure, psig	111.8	111.5
NTO Valve in Pressure, psig	226.3	226.1
MMH Valve in Pressure, psig	224.7	224.0
Regulator Out Pressure, psig	260.2	260.2
GN_2 Supply Pressure, psig	1614	1601

simulate flight propellant volumes. The GN_2 system was charged to 2550 psig and TEM-2 pressurized by firing the GN_2 isolation valve. After system pressurization, the propellant dump squib valves were activated, simulating an emergency propellant dump operation. It should be noted that very short lines were attached to the dump ports to direct the effluent into the test stand flame bucket; i.e., low back-pressure system was used. The following times were recorded:

- Propellant load exhaustion:
  - Fuel, seconds 48
  - Oxidizer, seconds 52
- GN_2 in 150 seconds

Based on this test, the following was concluded:

- TEM-1 and -2 emergency fluid dump times are satisfactory for mission requirements
- TEM-3 propellant dump time is expected to be shorter with higher regulator-out pressure (510 versus 220 psig)--estimated at 35 seconds to dump propellants.

There were no plans to conduct a similar test on TEM-3.

TEM-2 preparation for delivery consisted of the following operations:

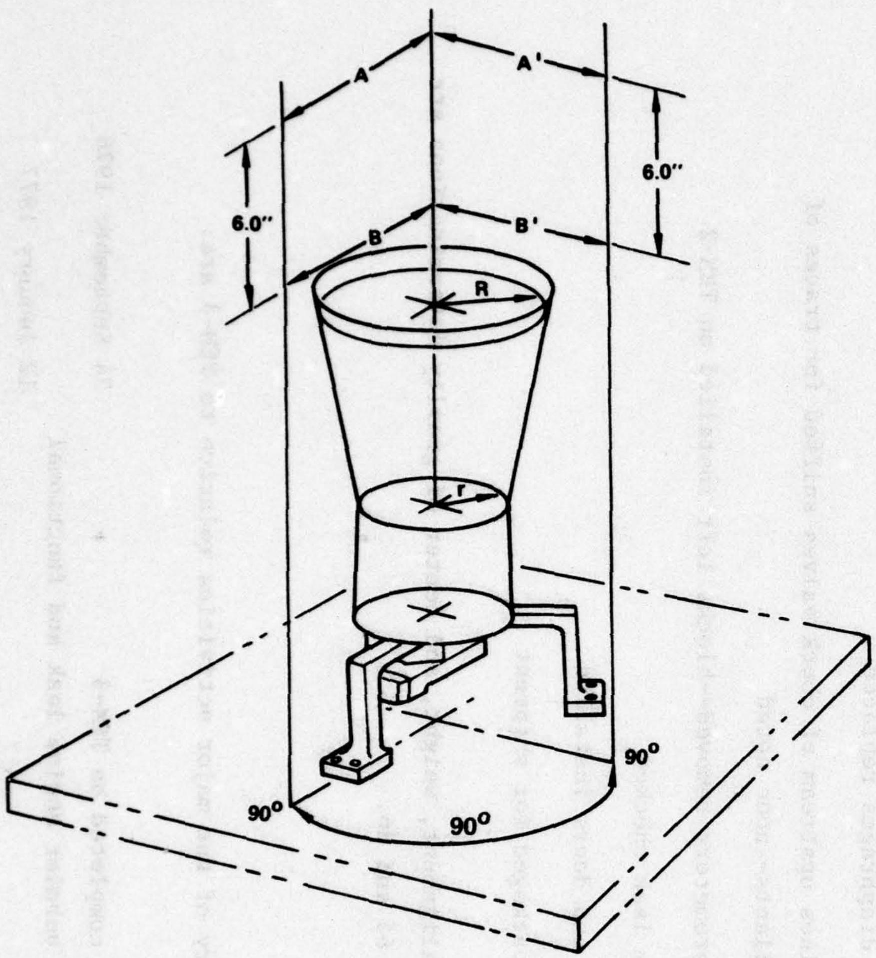
- Propellant decontamination
  - RS-14 engine removed and decontaminated per production specification RA0-230-289
  - Feed system decontaminated (flushed) during the emergency fluid dump test
  - Oxidizer and fuel systems vacuum dried and purged post dump test
- Filter elements cleaned and reassembled
- Expended squibs removed and shipping covers installed over ports
- Burst diaphragms replaced
- GN_2 lines upstream of check valves sniffed for traces of propellants--none noted
- Accelerometers removed--blocks left installed on TEM-2
- System leak checked
- Skins and doors installed
- Unit packaged for shipment

TEM-2 engine alignment, weight, and center of gravity determinations are shown in Fig. 65 and 66.

TEM-3 TESTING

A brief history of the major activities relative to TEM-3 are:

Assembly completed on TEM-3	24 September 1976
Complete vernier engine leak and functional test	12 January 1977
Cold-flow calibrations completed	26 January 1977



REQUIREMENT

0.1° (6')

MEASUREMENT

0.06° (3.6')

A-B = 0.0045"

A'-B' = 0.0025"

$$\text{RESULTANT} = \sqrt{\overline{A-B}^{2} + \overline{A'-B'}^{2}}$$

= 0.005138 "

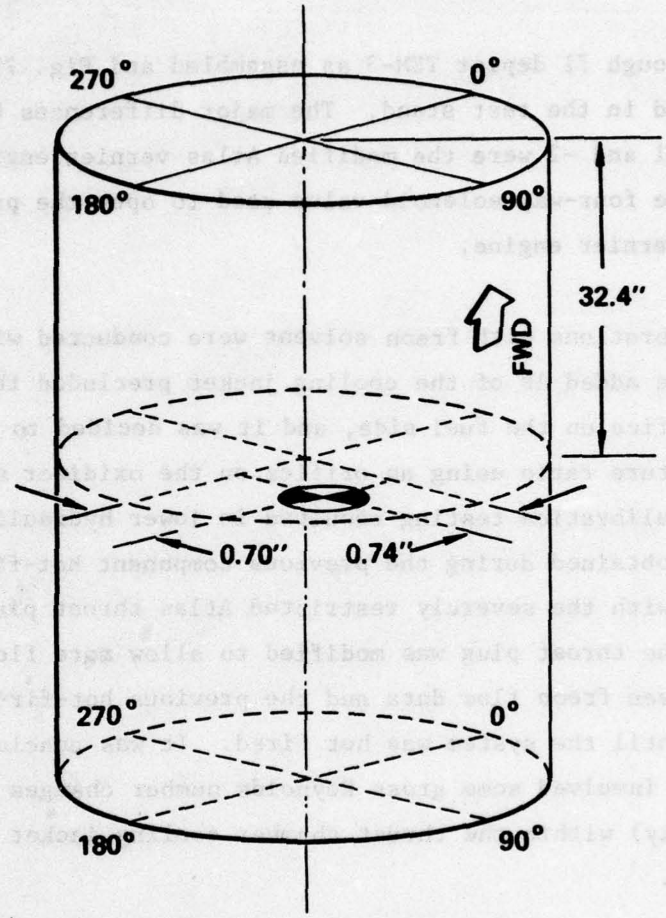
OR

0.0008563 IN/IN

TAN 0.1° = 0.0017

RESULTING ANGULAR ALIGNMENT IS 0.049057°

Figure 65. TEM-2 Engine Alignment



- Weight (dry), 485.5 LBm
- Engine Angular Alignment, 0.049 degrees

Figure 66. TEM-2 Weight, Center of Gravity, Engine Alignment

Module tanked with propellants	2 February 1977
Hot-fire mission duty cycle test	3 February 1977
Decontamination and refurbishment completed and ready for delivery	28 February 1977

Figures 67 through 71 depict TEM-3 as assembled and Fig. 72 shows TEM-3 installed in the test stand. The major differences between TEM-3 and TEM-1 and -2 were the modified Atlas vernier engine and the addition of the four-way solenoid valve used to open the propellant valve on the vernier engine.

Fuel-side calibrations with freon solvent were conducted with no orifice installed. The added ΔP of the cooling jacket precluded the installation of an orifice on the fuel side, and it was decided to trim the system for mixture ratio using an orifice on the oxidizer side of TEM-3. Fuel calibration testing resulted in lower hydraulic resistances than had been obtained during the previous component hot-fire tests. Initial tests with the severely restricted Atlas throat plugs were repeated after the throat plug was modified to allow more flow. The disagreement between freon flow data and the previous hot-fire data was not resolved until the system was hot fired. It was concluded that the difference involved some gross Reynolds number changes (density and/or viscosity) within the thrust chamber cooling jacket due to a heating effect.

Oxidizer subsystem calibrations were conducted with a 0.370-inch orifice installed. No problems were noted and this orifice was left in the system for the hot-fire tests. Target conditions for hot fire were shown in Fig. 8.

Agreement of oxidizer cold-flow hydraulic resistances versus the previous hot-fire data was good, indicating that the flowmeter data from the previous fuel calibrations was satisfactory.

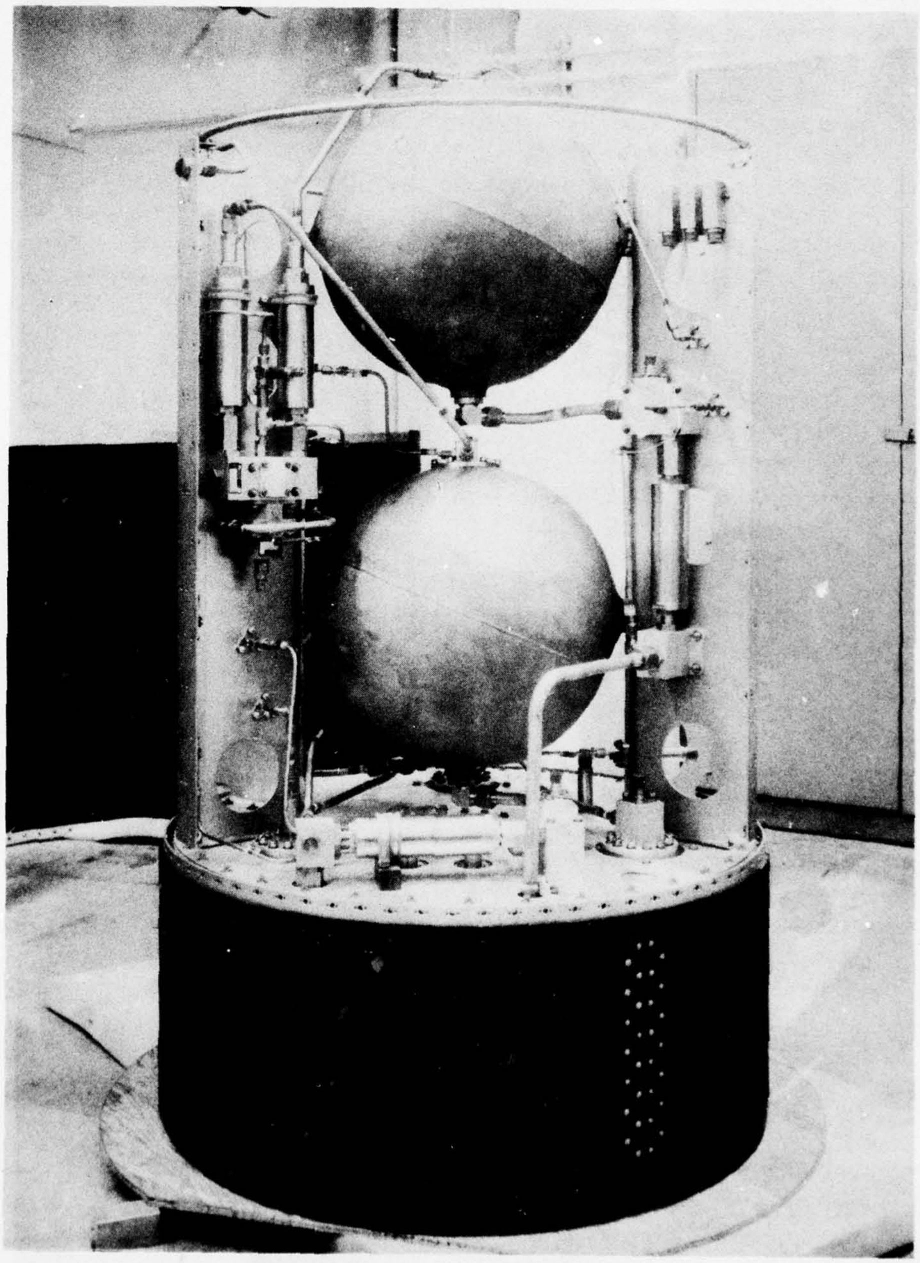


Figure 67. TEM-3 TES

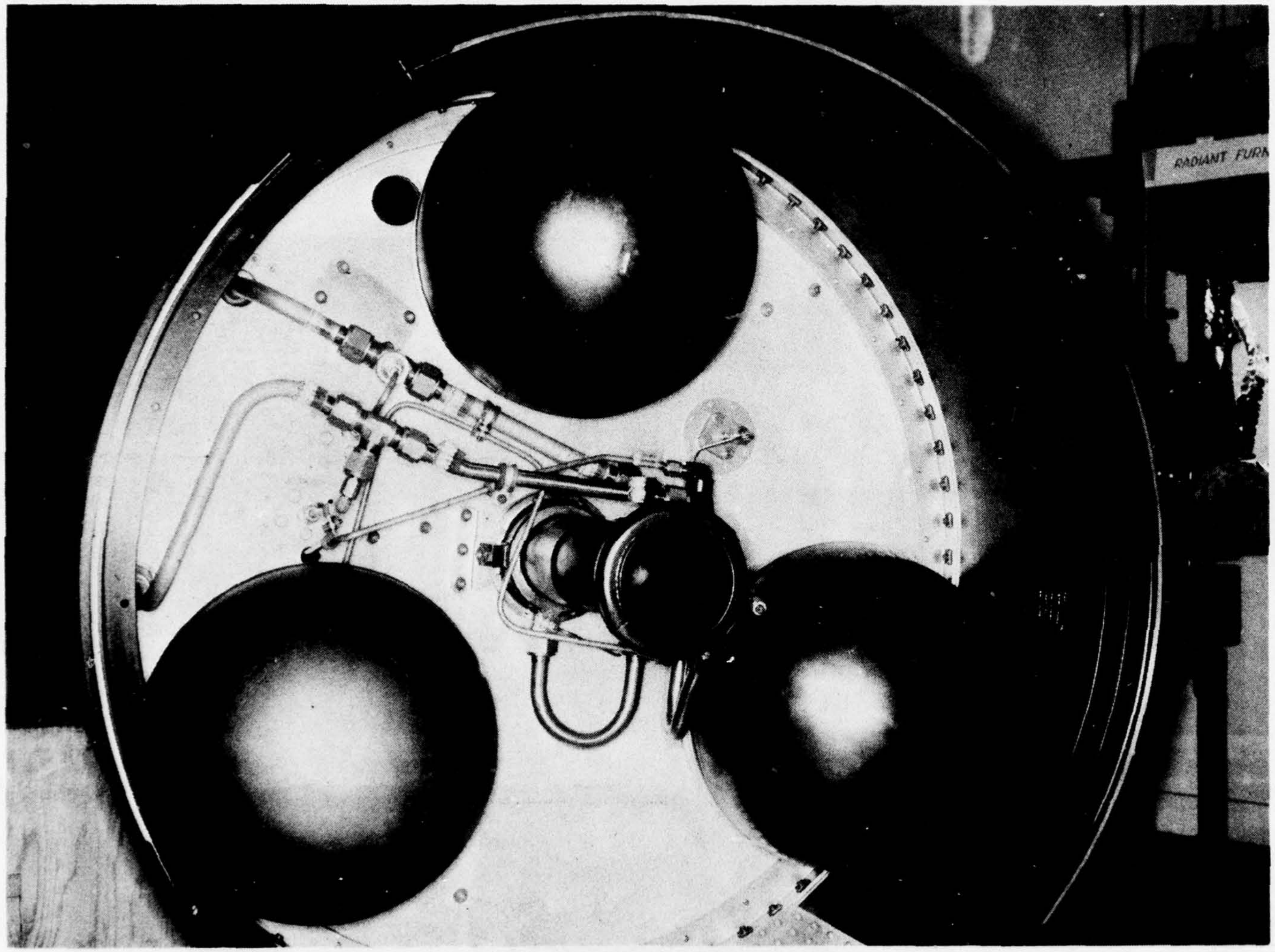


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Figure 68. TES TEM-3 Aft End

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Figure 69. TES TEM-3 Engine Installation

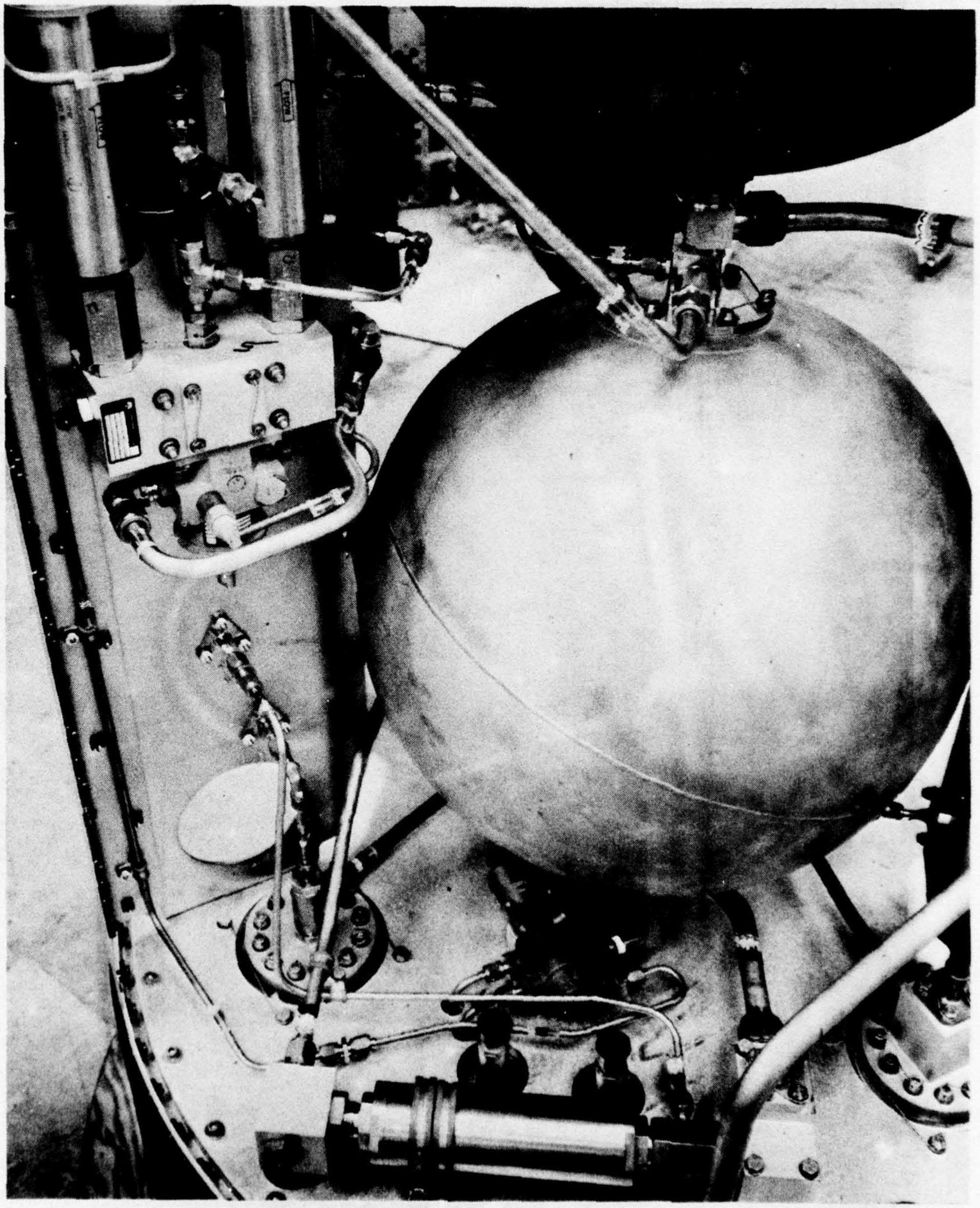

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Figure 70. TES TEM-3 Solenoid Valve Installation

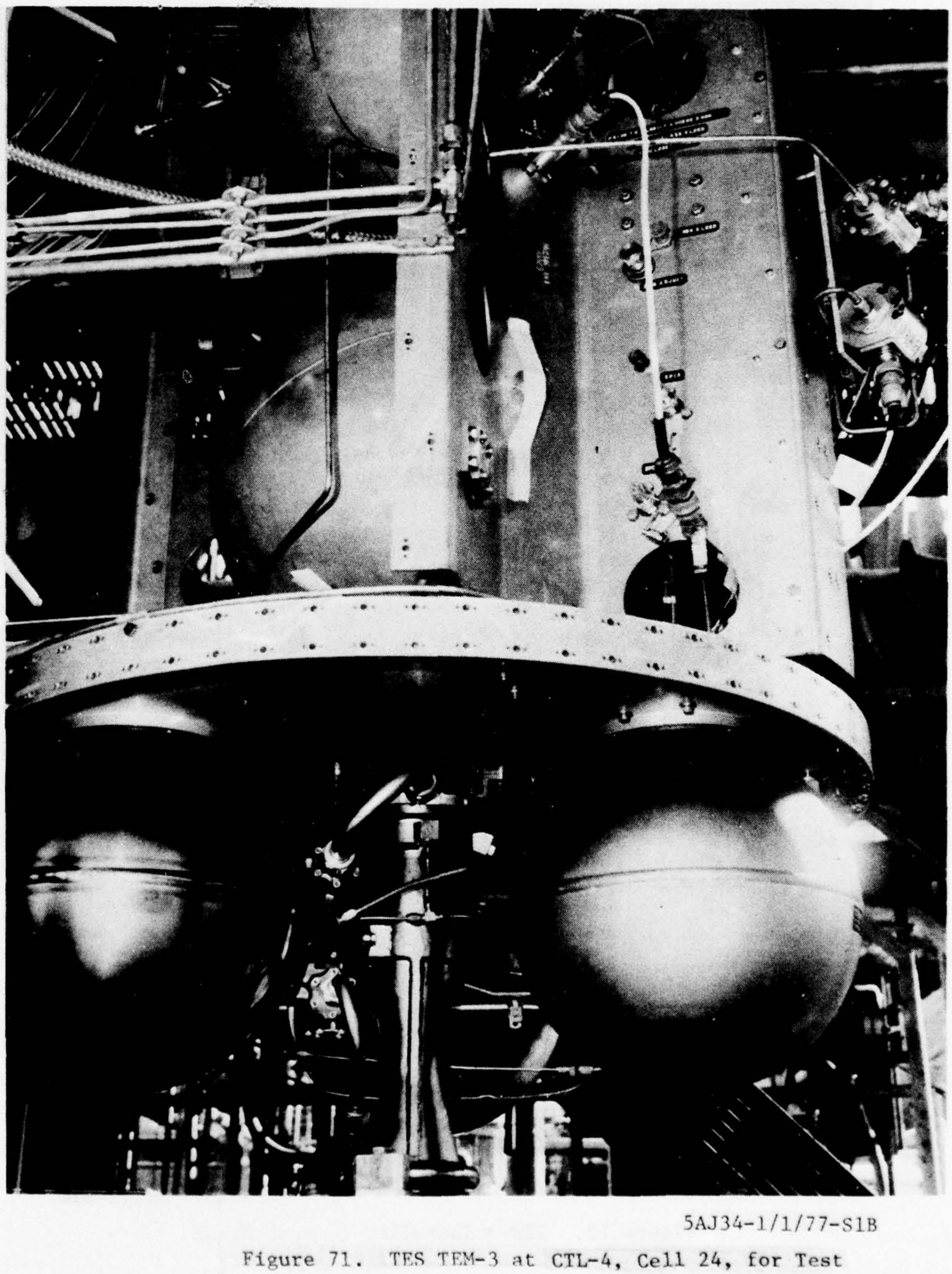

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Figure 71. TES TEM-3 at CTL-4, Cell 24, for Test

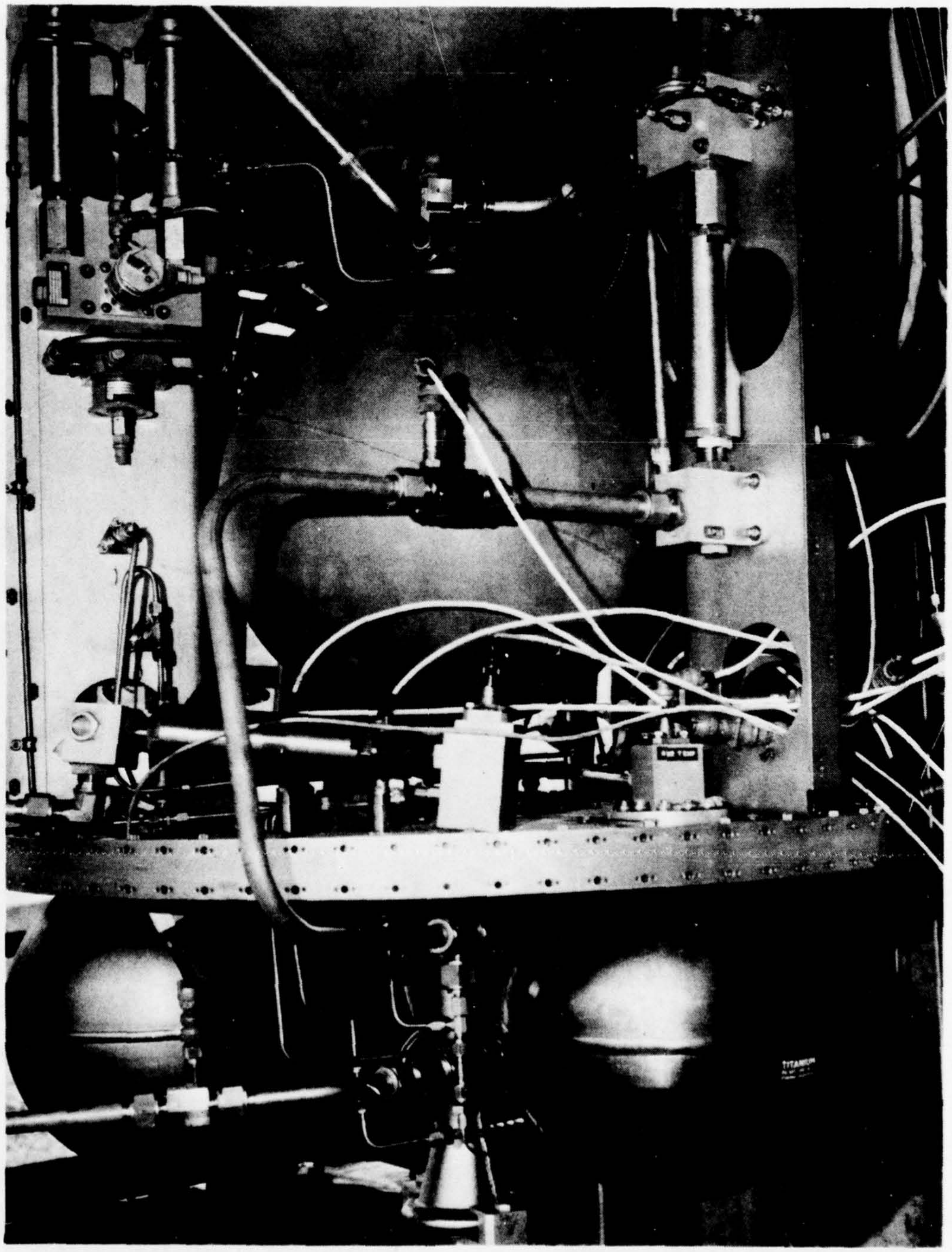

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Figure 72. TEM-3 Installed in Test Stand Showing Hot-Fire Flowmeters

Fuel system calibrations were repeated with an additional flowmeter and an additional inlet pressure measurement installed. Results were the same as before where the REA cold-flow hydraulic resistance was approximately 20% lower than the vernier engine hot-fire data. It was decided to proceed with the hot-fire portion of the test plan; only flowmeters would be added to determine flow and mixture ratio data. The TEM-3 propellant feed lines were modified with the addition of flowmeters as shown in Fig. 72. The additional ΔP with this arrangement was minimal and had little effect on test data.

Based on the cold-flow results, the following hot-fire setup was targeted:

- Fuel orifice size, wide open
- Oxidizer orifice size, 0.370 inch
- Regulator setting, 518 psia

Because of considerations regarding personnel safety around pressurized vessels in the test area, it was necessary to limit the initial pressurization of the TEM-3 GN_2 tanks to 1500 psig. To have sufficient GN_2 to complete the duty cycle, it was necessary to recharge the GN_2 tanks to 1500 psig after the pressurization transient. The hot-fire duty cycle consisted of five 5-second burns after which residual propellants were drained into the propellant servicing carts and weighed.

No significant hardware problems were noted although a strange phenomenon was noted within seconds after each shutdown transient in the form of an audible tone with changing pitch. This phenomenon lasted 30 to 60 seconds after each burn but did not cause any hardware damage. This was most likely due to residual MMH in the jacket which boiled away from heat soakback effects and on occasion would ignite and burn in the surrounding atmosphere. The burning and/or noise phenomenon is not expected to occur in a hard vacuum as rapid dispersal of the MMH should occur at altitude. Although mixture ratio was slightly high, approximately

1.7 versus the expected 1.6, the data were as expected. Agreement of the flight pressure data versus the facility backup transducers is shown in Table 22.

TABLE 22. TEM-3 FACILITY AND FLIGHT INSTRUMENTATION COMPARISON

Parameter	TEM	Facility
Chamber Pressure, psig	338.9	336.0
NTO Valve in Pressure, psig	426.8	424.5
MMH Value in Pressure, psig	462.5	457.0
Regulator Out Pressure, psig	498.8	498.1
GN_2 Supply Pressure, psig	1289	1296

The following operations were performed in preparation for delivery to the Air Force.

- Propellant decontamination
  - Vernier engine (-3) removed and decontaminated
  - Feed systems decontaminated (flushed)
  - Oxidizer and fuel systems vacuum dried and purged
- Vernier engine was disassembled
  - O-rings replaced at injector/thrust chamber
  - Rebuilt propellant valve installed
  - Vernier engine leak and functionally checked
- Filter elements cleaned and reassembled
- Expended squibs removed and shipping covers installed over ports
- Burst diaphragms replaced
- GN_2 lines upstream of check valves sniffed for traces of propellants--none noted

- System leak checked
- Skins and doors installed
- Unit packaged for shipment

Previously, the weight and center of gravity had been determined and is shown in Fig. 73. Engine alignment was rechecked after the rebuild of the vernier engine. Results of alignment are shown in Fig. 74.

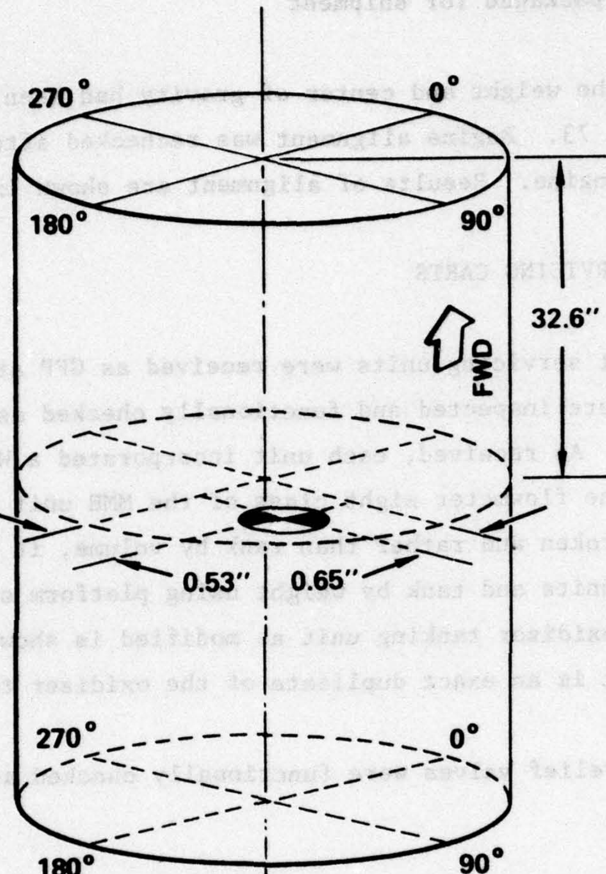
PROPELLANT SERVICING CARTS

Two propellant servicing units were received as GFP at Rocketdyne. These units were inspected and functionally checked as to condition and function. As received, each unit incorporated a Wallace Tiernan flowmeter. The flowmeter sight glass of the MMH unit flowmeter was found to be broken and rather than tank by volume, it was decided to modify these units and tank by weight using platform scales. A schematic of the oxidizer tanking unit as modified is shown in Fig. 75. The fuel unit is an exact duplicate of the oxidizer tanking unit.

The MMH unit relief valves were functionally checked and the following values noted:

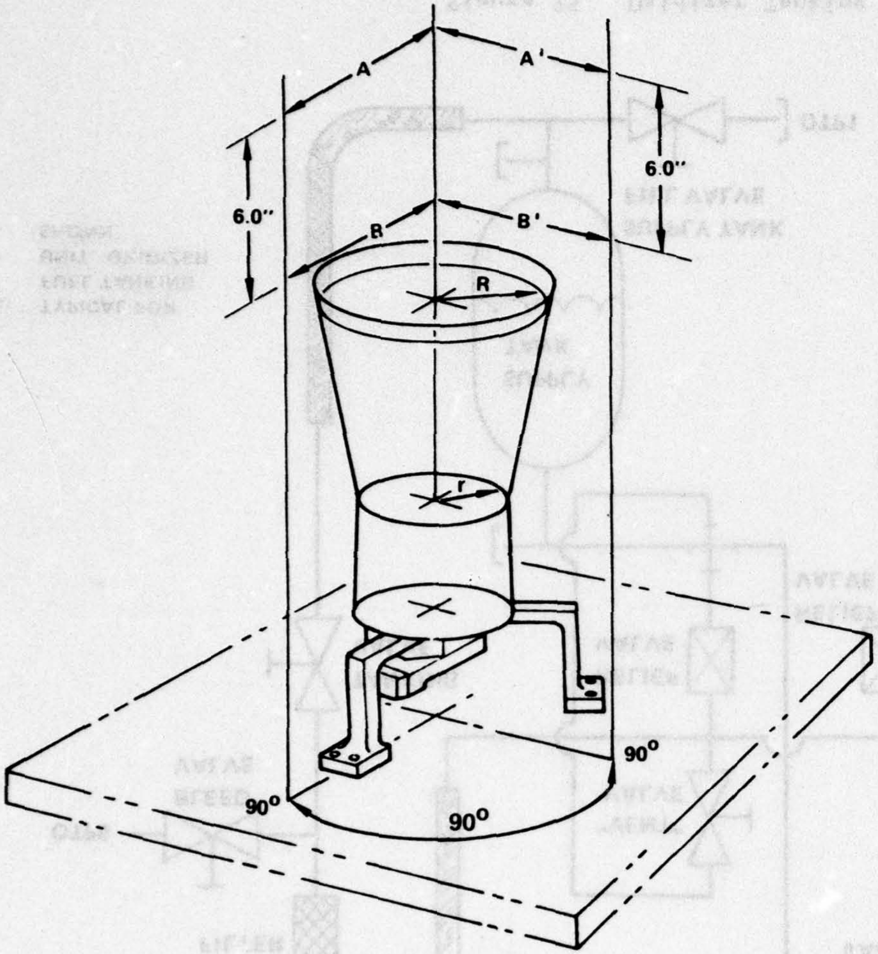
Cracking pressure, psig	140 and 144
Maximum flow pressure, psig	162 and 166
Reseat pressure, psig	136 and 142

The supply tank in the MMH unit was proof-pressure cycled three times at 200 psig for 3 minutes minimum. The tanking filter element was removed and cleaned with isopropyl alcohol, then dried with GN_2; this filter was remounted at the end of the tanking line. The entire unit was then leak checked at 100 psig.



- Weight (dry), 487.4 LBm
- Engine Angular Alignment, 0.07 degrees

Figure 73. TEM-3 Weight, Center of Gravity, Engine Alignment



REQUIREMENT

0.1^{0} (6')

MEASUREMENT

0.07^{0} (4.2')

$A-B = 0.006''$

$A'-B' = 0.004''$

$$\text{RESULTANT} = \sqrt{\overline{A-B}^{2} + \overline{A'-B'}^{2}}$$

$$= 0.00721''$$

OR

0.0018 IN/IN

$\text{TAN } 0.1^{0} = 0.0017$

RESULTING ANGULAR ALIGNMENT IS 0.0675^{0}

Figure 74. TEM-3 Engine Alignment

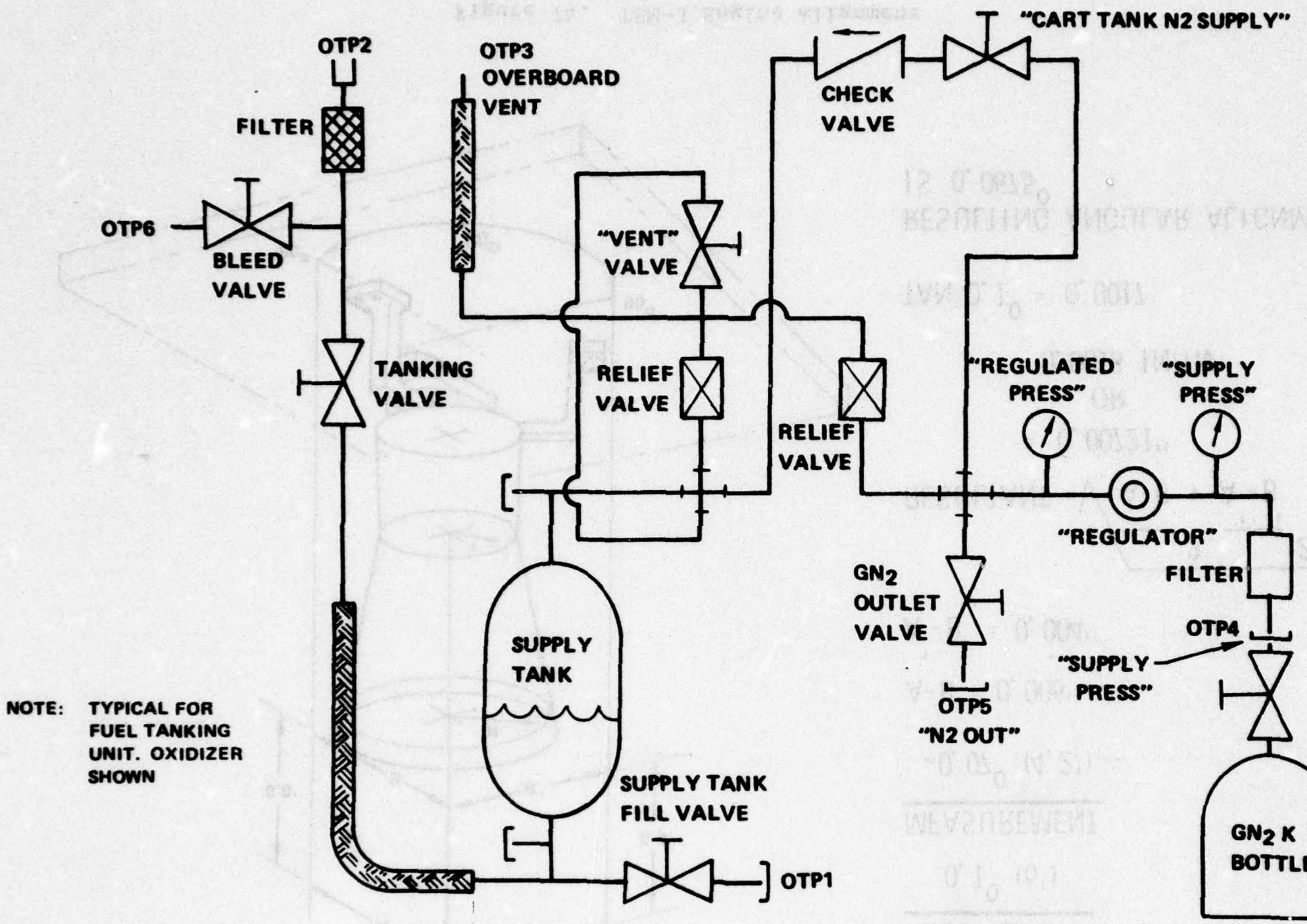


Figure 75. Oxidizer Tanking Unit

Likewise, the NTO tanking unit was functionally checked and relief valve pressures noted as follows:

Cracking pressure, psig	136 and 144
Maximum flow pressure, psig	165 and 170
Reseat pressure, psig	132 and 138

The supply tank in the NTO unit also was proof-pressure cycled three times at 200 psig for 3 minutes minimum. The tanking filter element was cleaned with freon solvent, dried with GN_2, and remounted at the end of the tanking line. The entire NTO unit was then leak checked at 100 psig.

Both tanking units were utilized in the oxidizer and fuel tanking, detanking, and decontamination operations for the TEM-1, -2, and -3 hot-fire operations at SSFL. No difficulties were encountered except that one hand-operated valve for the fuel tanking unit developed a leak at the valve handle packing; a replacement valve is available for TEM-1 flight operations at WSMR.

DATA ASSESSMENT

The hot-fire performance of TEM-1, -2, and -3 was satisfactory in every way. The site test data were input into the nonlinear computer model for the purpose of establishing hardware characteristics and predicting performance for specified input conditions. A sample of the model output for TEM-3 is depicted in Fig. 76. Tables 23 through 25 depict the site hot-fire performance for each TEM duty cycle. It should be noted that the thrust values presented are calculated for altitude (i.e., $P_A = 0$). The predicted performance for each TEM, based on a standard regulator pressure of 270 psia for TEM-1 and -2, 520 psi for TEM-3 and standard propellant densities, is presented in Tables 26 through 28.

RUN

TEM3V 16:43 RI T/S APR 14, 1977

APR 14, 1977

FIXED HARDWARE

THRUST	LB	1179.	C-STAR ACTUAL	FT/SEC	5040.
MIXTURE RATIO		1.699	C-STAR EFFICIENCY		.8772
SPECIFIC IMPULSE	SEC	252.3	C-STAR THEORETICAL	FT/SEC	5746.
CHAMBER PRESSURE	PSIA	358.1	C-SUB-F ACTUAL		1.61
NTO FLOWRATE	LB/SEC	2.942	C-SUB-F EFFICIENCY		.9723
MMH FLOWRATE	LB/SEC	1.732	C-SUB-F THEORETICAL		1.656
TOTAL FLOWRATE	LB/SEC	4.674	NOZZLE STAG PR	PSIA	348.8
NTO DENSITY	LB/FT3	90.17	THROAT AREA	SQ IN	2.1
MMH DENSITY	LB/FT3	54.55	EXPANSION AREA RATIO		5.568
AMBIENT PRESSURE	PSIA	0			
NTO TANK PRESSURE	PSIA	498			
MMH TANK PRESSURE	PSIA	498			
NTO VALVE IN PR	PSIA	451.9			
MMH VALVE IN PR	PSIA	486.8			
REG REF PR	PSIA	520			

NTO RESISTANCES

(TNK TO PC)	(ORF + LN)	(ORF)	(LINE)	(VLV TO PC)
1477.	500.18	273.38	226.8	976.78
157.41	53.307	29.136	24.172	104.1
.37				

MMH RESISTANCES

2551.4	211.3	0	211.3	2340.1
168.85	13.983	0	13.983	154.86
.609				

Figure 76. TEM Nonlinear Model Printout

TABLE 23. TEM-1 HOT-FIRE PERFORMANCE (SITE)

PARAMETER		TEST					
		006	007	008	009	010	011
THRUST (ALTITUDE)	LB	315.6	317.3	317.8	318.1	318.3	318.8
MIXTURE RATIO		1.564	1.561	1.562	1.560	1.561	1.559
SPECIFIC IMPULSE	SEC	283.9	285.6	285.9	286.8	286.6	286.8
CHAMBER PRESSURE	PSIA	126.1	126.8	127.0	127.1	127.2	127.4
NTO FLOWRATE	LB/SEC	.6782	.6772	.6777	.6758	.6769	.6771
MMH FLOWRATE	LB/SEC	.4337	.4340	.4339	.4331	.4336	.4343
TOTAL FLOWRATE	LB/SEC	1.112	1.111	1.112	1.109	1.111	1.111
NTO DENSITY	LB/FT3	91.38	91.43	91.41	91.38	91.36	91.32
MMH DENSITY	LB/FT3	55.08	55.10	55.09	55.08	55.06	55.04
NTO VALVE IN PR	PSIA	239.5	239.8	240.2	239.7	240.2	240.5
MMH VALVE IN PR	PSIA	246.5	247.3	247.5	247.2	247.6	248.2
REG REF PR	PSIA	272.3	273.3	273.7	273.5	274.1	274.9
C-STAR ACTUAL	FT/SEC	5184.	5217.	5222.	5239.	5236.	5240.
C-STAR EFFICIENCY		.9090	.9148	.9157	.9187	.9181	.9189
C-STAR THEORETICAL	FT/SEC	5703.	5703.	5703.	5703.	5703.	5702.
C-SUB-F ACTUAL		1.762	1.761	1.761	1.761	1.761	1.761
C-SUB-F EFFICIENCY		.9617	.9617	.9617	.9617	.9617	.9617
C-SUB-F THEORETICAL		1.832	1.831	1.832	1.831	1.832	1.831
NOZZLE STAG PR	PSIA	124.9	125.5	125.7	125.8	125.9	126.1
THROAT AREA	SQ IN	1.435	1.435	1.435	1.435	1.435	1.435
EXPANSION AREA RATIO		30.06	30.06	30.06	30.06	30.06	30.06

TABLE 24. TEM-2 HOT-FIRE PERFORMANCE (SITE)

PARAMETER		TEST					
		013	014	015	016	017	018
THRUST (ALTITUDE)	LB	297.9	310.3	311.3	313.1	313.1	314.3
MIXTURE RATIO		1.603	1.603	1.611	1.603	1.604	1.604
SPECIFIC IMPULSE	SEC	285.7	285.7	286.4	288.3	288.7	288.6
CHAMBER PRESSURE	PSIA	119.	124.	124.3	125.1	125.1	125.6
NTO FLOWRATE	LB/SEC	.6421	.6691	.6707	.6687	.668	.6707
MMH FLOWRATE	LB/SEC	.4005	.4173	.4164	.4173	.4165	.4182
TOTAL FLOWRATE	LB/SEC	1.043	1.086	1.087	1.086	1.084	1.089
NTO DENSITY	LB/FT3	89.29	89.26	89.28	89.17	89.14	89.11
MMH DENSITY	LB/FT3	54.12	54.11	54.11	54.08	54.07	54.06
NTO VALVE IN PR	PSIA	223.9	237.9	238.8	239.1	238.8	240.3
MMH VALVE IN PR	PSIA	222.6	236.5	236.4	237.7	237.2	238.7
REG REF PR	PSIA	255.9	271.4	272.2	272.1	272.1	274.
C-STAR ACTUAL	FT/SEC	5197.	5198.	5208.	5247.	5254.	5252.
C-STAR EFFICIENCY		.9107	.9106	.9123	.9192	.9204	.9202
C-STAR THEORETICAL	FT/SEC	5707.	5708.	5709.	5708.	5708.	5708.
C-SUB-F ACTUAL		1.769	1.768	1.769	1.768	1.768	1.768
C-SUB-F EFFICIENCY		.9624	.9624	.9624	.9624	.9624	.9624
C-SUB-F THEORETICAL		1.838	1.837	1.838	1.837	1.837	1.837
NOZZLE STAG PR	PSIA	117.8	122.8	123.1	123.9	123.9	124.4
THROAT AREA	SQ IN	1.429	1.429	1.429	1.429	1.429	1.429
EXPANSION AREA RATIO		30.16	30.16	30.16	30.16	30.16	30.16

TABLE 25. TEM-3 HOT-FIRE PERFORMANCE (SITE)

PARAMETER		TEST 001	002	003	004	005
THRUST (ALTITUDE)	LB	1190.	1162.	1151.	1150.	1144.
MIXTURE RATIO		1.706	1.699	1.69	1.7	1.706
SPECIFIC IMPULSE	SEC	254.7	251.9	249.2	251.9	252.7
CHAMBER PRESSURE	PSIA	361.4	352.8	349.6	349.3	347.1
NTO FLOWRATE	LB/SEC	2.946	2.904	2.901	2.876	2.853
MMH FLOWRATE	LB/SEC	1.727	1.709	1.717	1.691	1.672
TOTAL FLOWRATE	LB/SEC	4.673	4.613	4.619	4.567	4.525
NTO DENSITY	LB/FT3	91.71	91.67	91.67	91.6	91.59
MMH DENSITY	LB/FT3	55.14	55.11	55.1	55.07	55.06
NTO TANK PRESSURE	PSIA	499.5	490.6	488.	485.2	483.3
MMH TANK PRESSURE	PSIA	499.5	490.6	488.	485.2	483.3
NTO VALVE IN PR	PSIA	444.9	443.	440.5	440.4	441.5
MMH VALVE IN PR	PSIA	483.6	477.7	474.5	473.1	473.1
REG REF PR	PSIA	521.5	512.6	510.	507.2	505.3
C-STAR ACTUAL	FT/SEC	5088.	5032.	4980.	5032.	5047.
C-STAR EFFICIENCY		.8854	.8759	.867	.876	.8785
C-STAR THEORETICAL	FT/SEC	5747.	5745.	5744.	5745.	5745.
C-SUB-F ACTUAL		1.611	1.61	1.61	1.611	1.611
C-SUB-F EFFICIENCY		.9723	.9723	.9723	.9723	.9723
C-SUB-F THEORETICAL		1.657	1.656	1.656	1.656	1.657
NOZZLE STAG PR	PSIA	352.	343.6	340.5	340.2	338.1
THROAT AREA	SQ IN	2.1	2.1	2.1	2.1	2.1
EXPANSION AREA RATIO		5.568	5.568	5.568	5.568	5.568

TABLE 26. TEM-1 PREDICTED PERFORMANCE

• Input	
• Regulator Pressure, psia	270.0
• Ambient Pressure, psia	0
• NTO Density, lb/ft^3	90.17
• MMH Density, lb/ft^3	54.55
• Output	
• Thrust, pounds	313.7
• I_{sp}, seconds	285.8
• Mixture Ratio	1.557
• NTO Flowrate, lb/sec	0.6682
• MMH Flowrate, lb/sec	0.4292
• NTO Valve in Pressure, psiat	236.9
• MMH Valve in Pressure, psiat	244.4
• P_c, psia	125.4

TABLE 27. TEM-2 PREDICTED PERFORMANCE

• Input	
• Regulator Out Pressure, psia	270.0
• Ambient Pressure, psia	0
• NTO Density, lb/ft^3	90.17
• MMH Density, lb/ft^3	54.55
• Output	
• Thrust, pounds	311.8
• I_{sp}, seconds	287.6
• Mixture Ratio	1.608
• NTO Flowrate, lb/sec	0.6683
• MMH Flowrate, lb/sec	0.4156
• NTO Valve in Pressure, psiat	237.1
• MMH Valve in Pressure, psiat	235.2
• P_c, psia	124.5

TABLE 28. TEM-3 PREDICTED PERFORMANCE

• Input	
• Regulator Out Pressure, psia	520.0
• Ambient Pressure, psia	0
• NTO Density, lb/ft^3	90.17
• MMH Density, lb/ft^3	54.55
• Output	
• Thrust, pounds	1179.0
• I_{sp}, seconds	252.3
• Mixture Ratio	1.699
• NTO Flowrate, lb/sec	2.942
• MMH Flowrate, lb/sec	1.732
• NTO Valve in Pressure, psiat	451.9
• MMH Valve in Pressure, psiat	486.8
• P_c, psia	358.1

Scaled site data as a function of time for TEM-1 pressurization and first burn are presented in CRT format (Fig. 77 through 89). Figures 90 through 97 depict CRT data for TEM-2 first burn; pressurization data for TEM-2 were not obtained. TEM-3 pressurization transient and first burn CRT's are presented in Fig. 98 through 110.

An anomaly was observed during TEM-1 and -3 pressurization transients. As depicted in Fig. 111, for TEM-1, the GN_2 tank pressure dropoff during propellant tank pressurization was greater than expected. This has been attributed to 2.2 pounds of GN_2 leaking overboard through the propellant tank relief valve which characteristically relieves when subjected to a rapid (step) rate of change of pressure. Approximately 2.6 pounds of GN_2 were dumped overboard during TEM-3 pressurization. The effect of this overboard dumping is to slow the tank pressurization rate and decrease the available GN_2. Assuming the relief valve performs repeatedly, no problems, relative to meeting mission duty cycles, are anticipated.

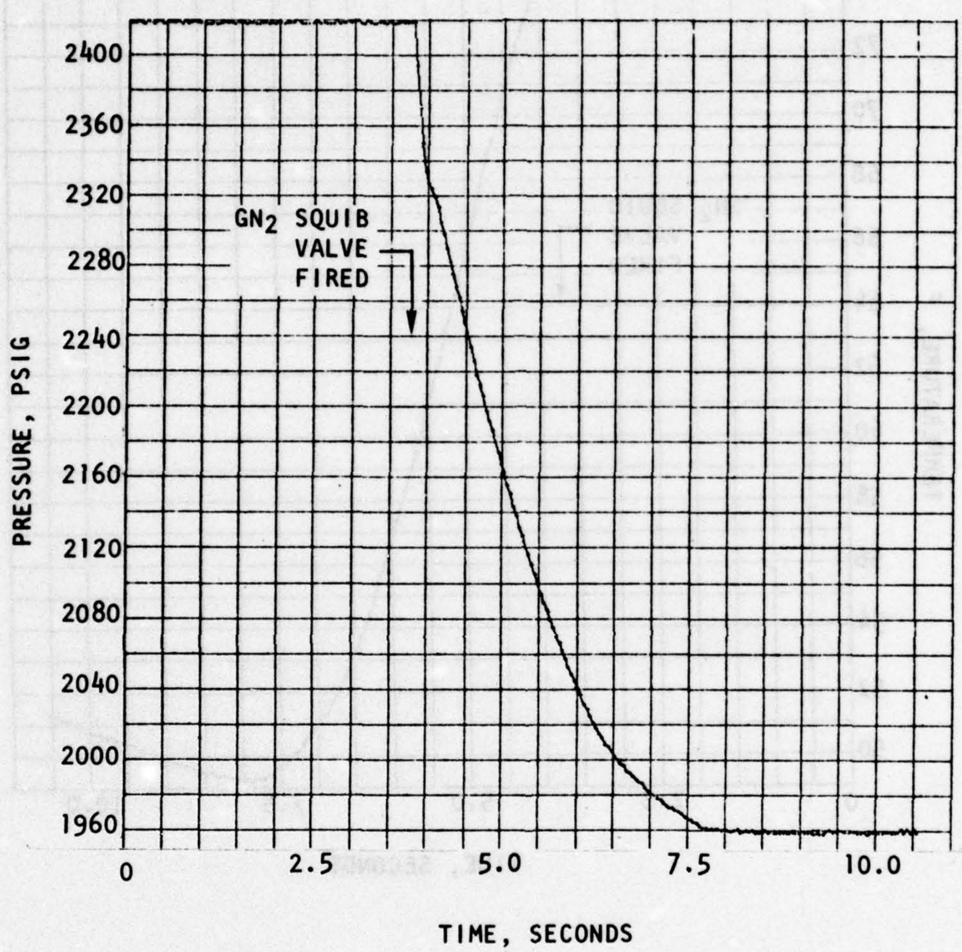


Figure 77. TEM-1 Pressurization Transient GN_2 Tank Pressure

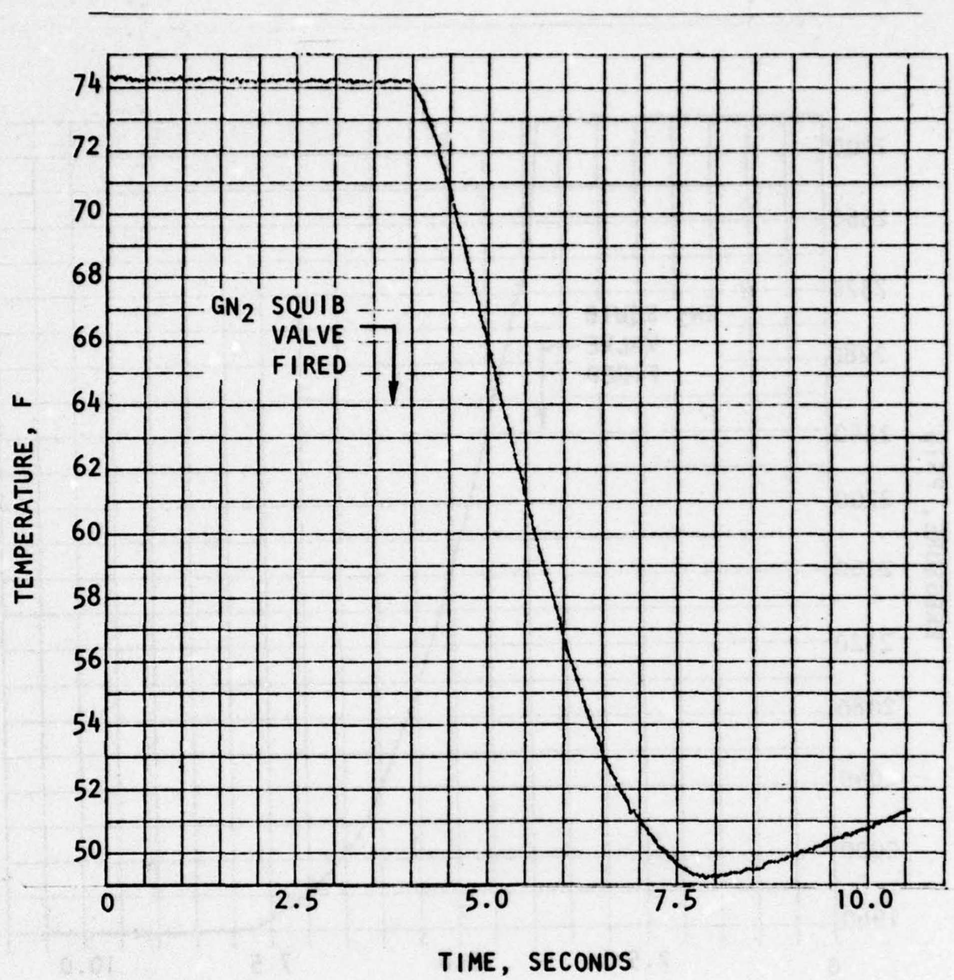


Figure 78. TEM-1 Pressurization Transient GN_2 Tank Temperature

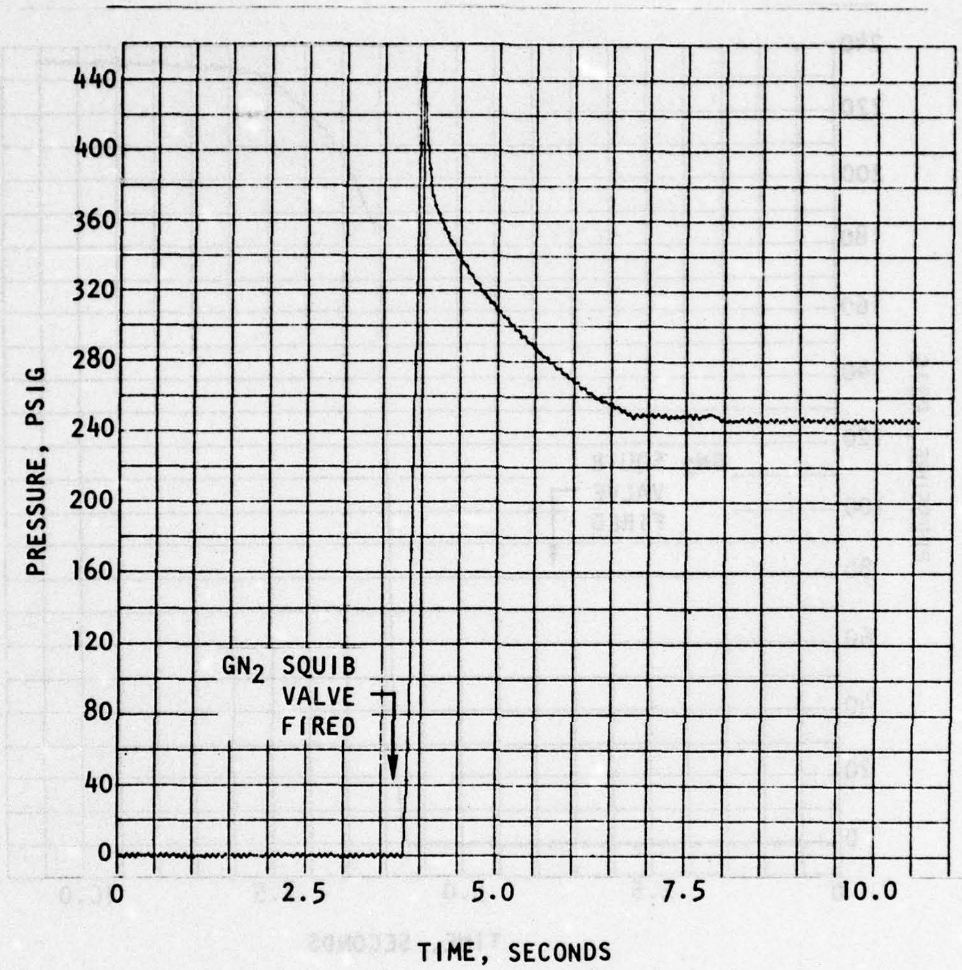


Figure 79. TEM-1 Pressurization Transient Regulator Outlet Pressure

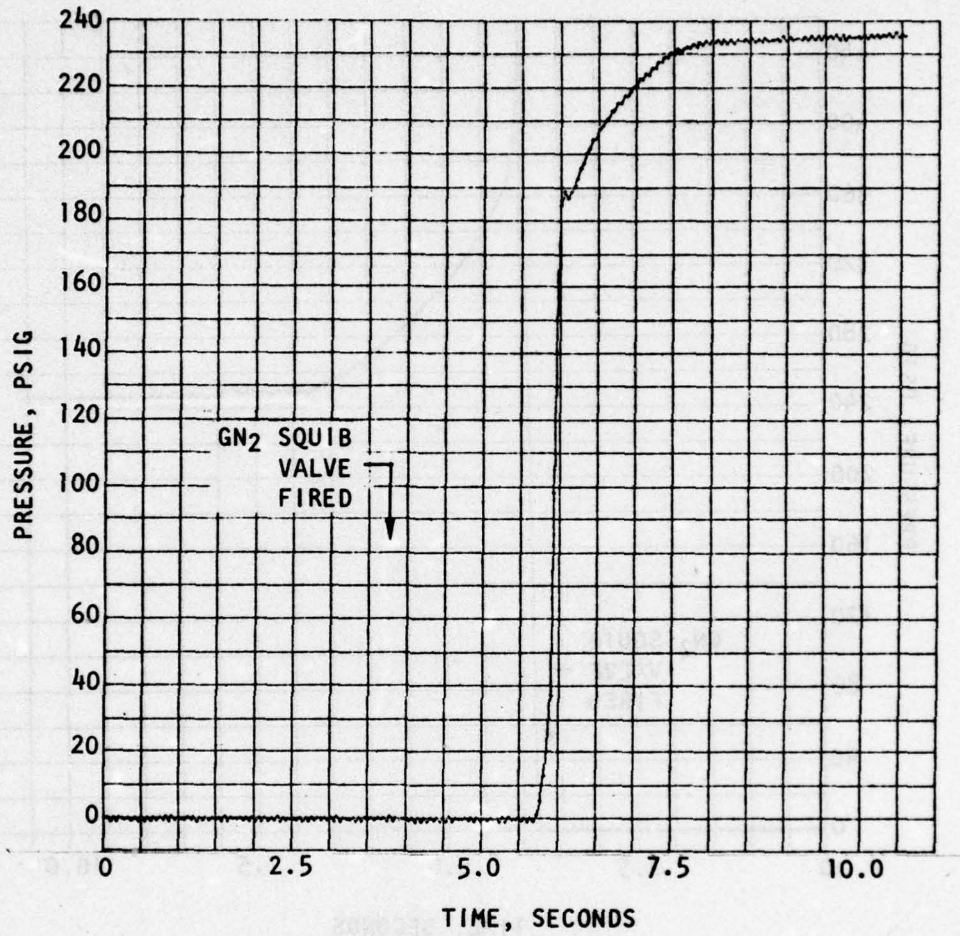


Figure 80. TEM-1 Pressurization Transient MMH Inlet Pressure

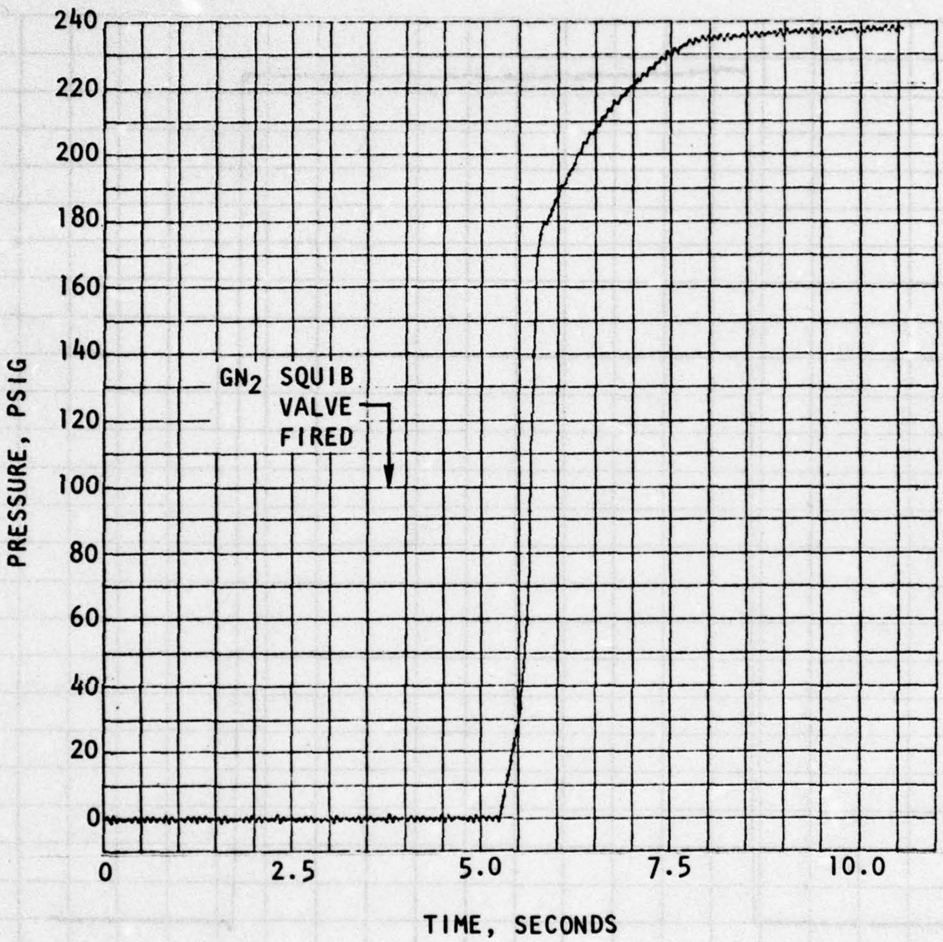


Figure 81. TEM-1 Pressurization Transient NTO Inlet Pressure

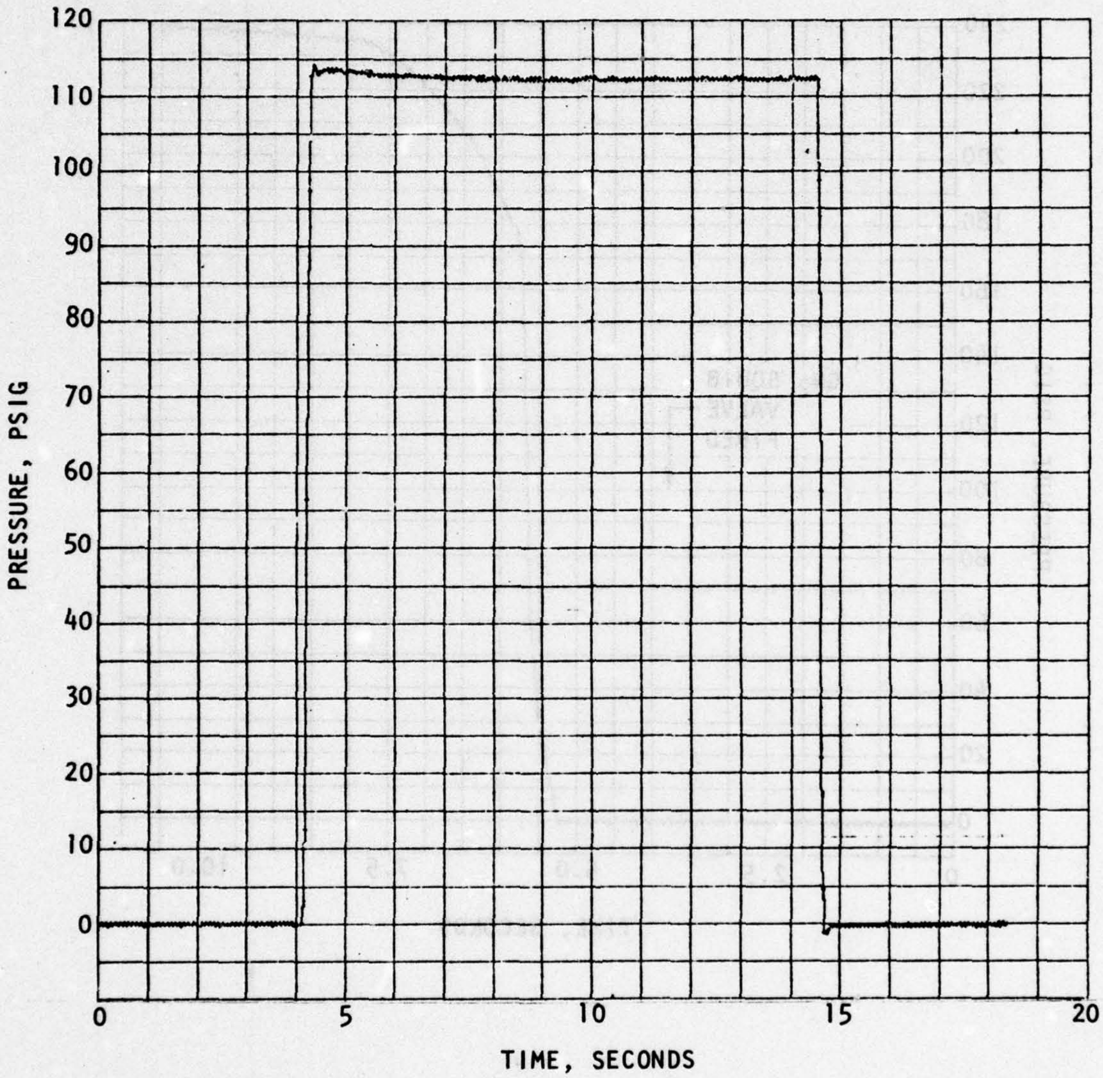


Figure 82. TEM-1 First Burn (Test 846-006) Chamber Pressure

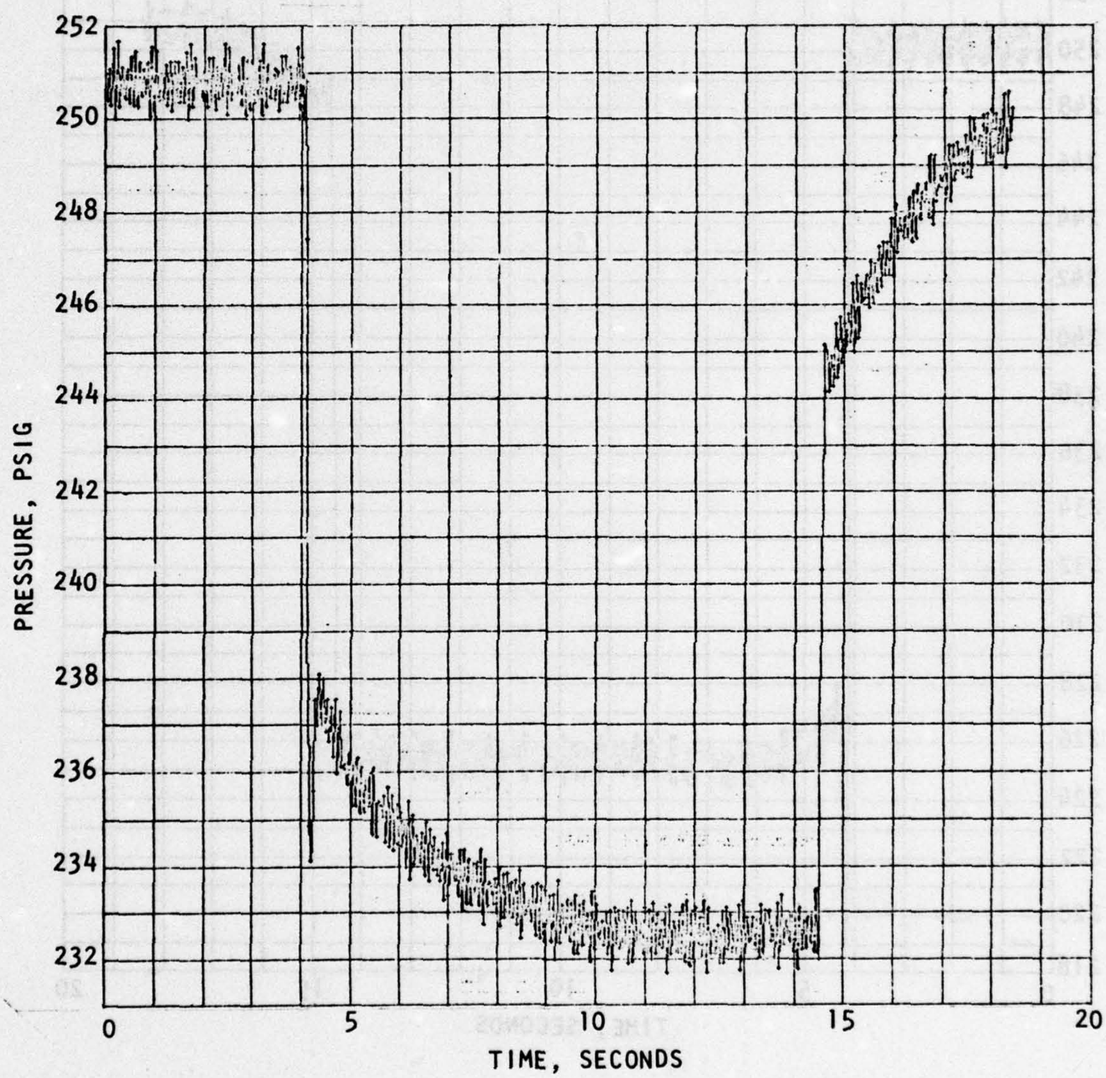


Figure 83. TEM-1 First Burn (Test 846-006) MMH Inlet Pressure

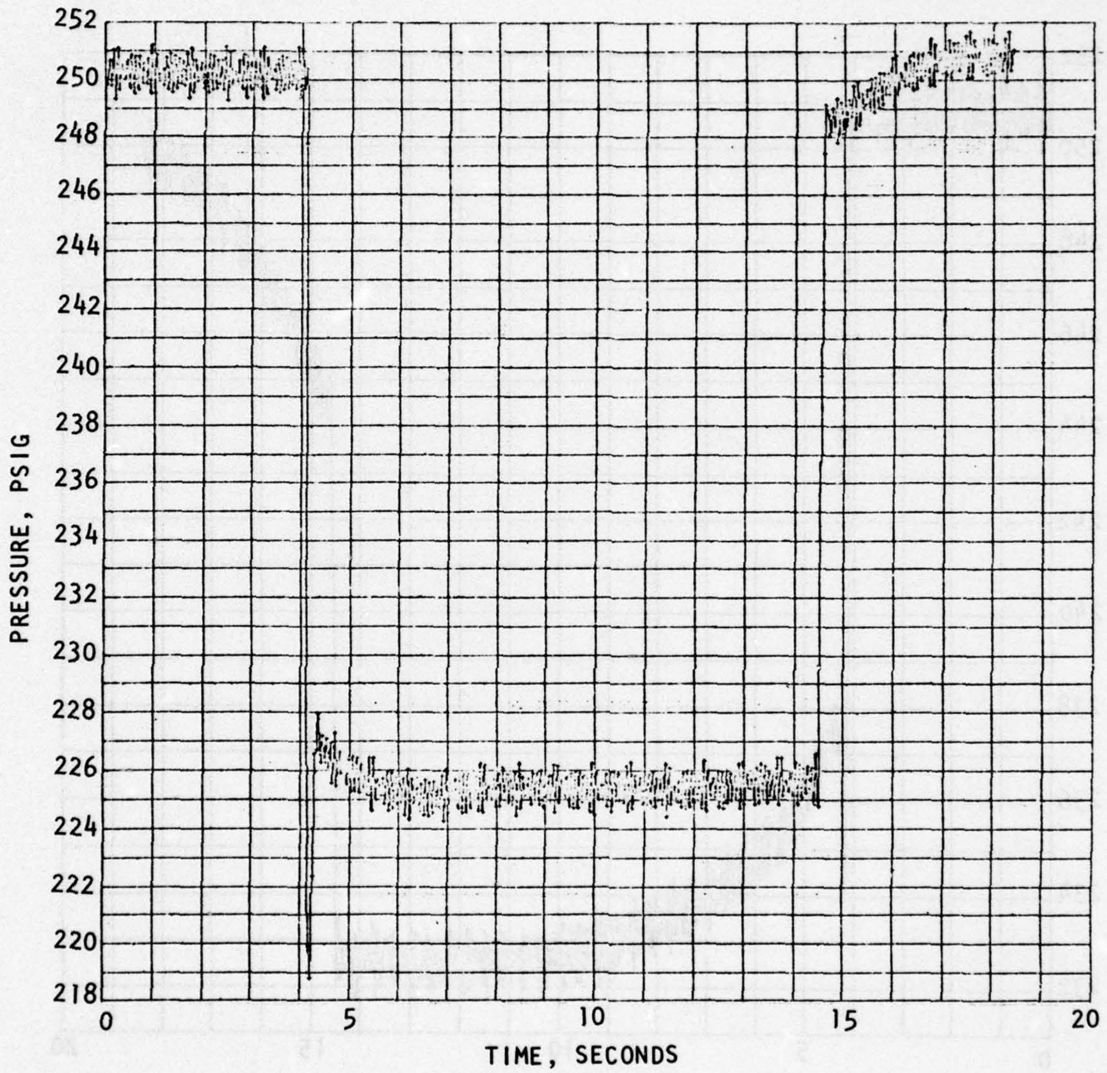


Figure 84. TEM-1 First Burn (Test 846-006) NTO Inlet Pressure

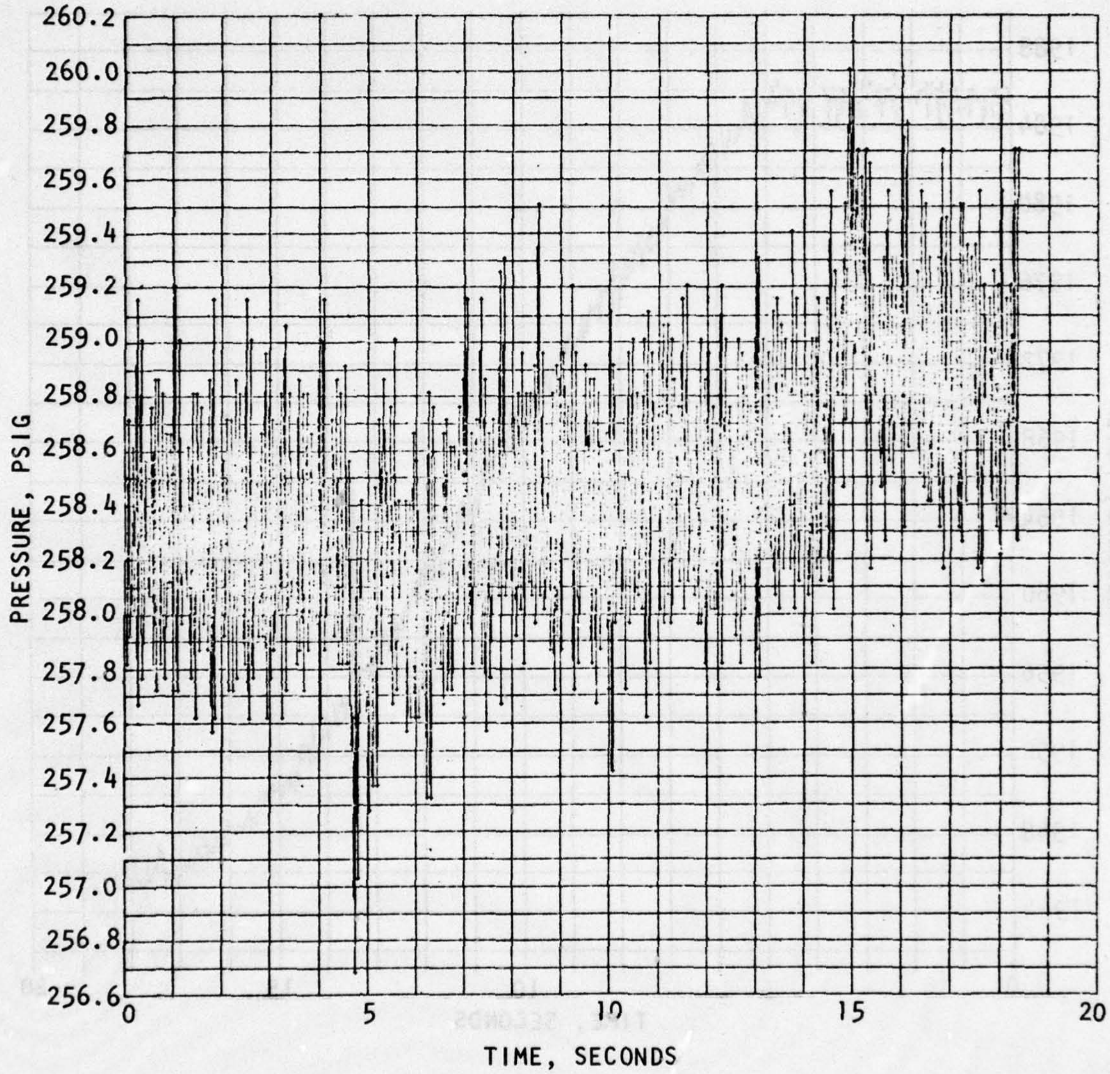


Figure 85. TEM-1 First Burn (Test 846-006) Regulator Outlet Pressure

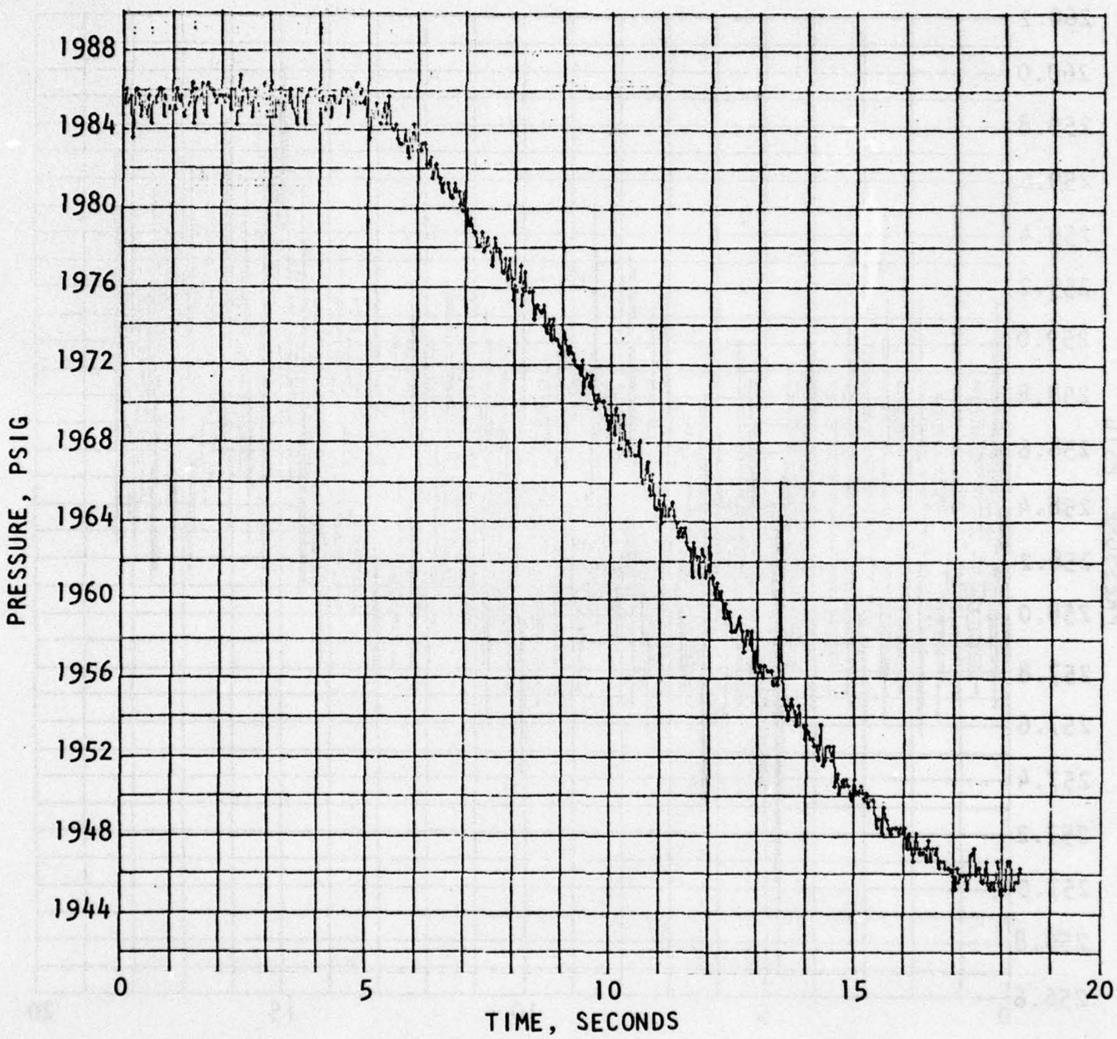


Figure 86. TEM-1 First Burn (Test 846-006) GN_2 Tank Pressure

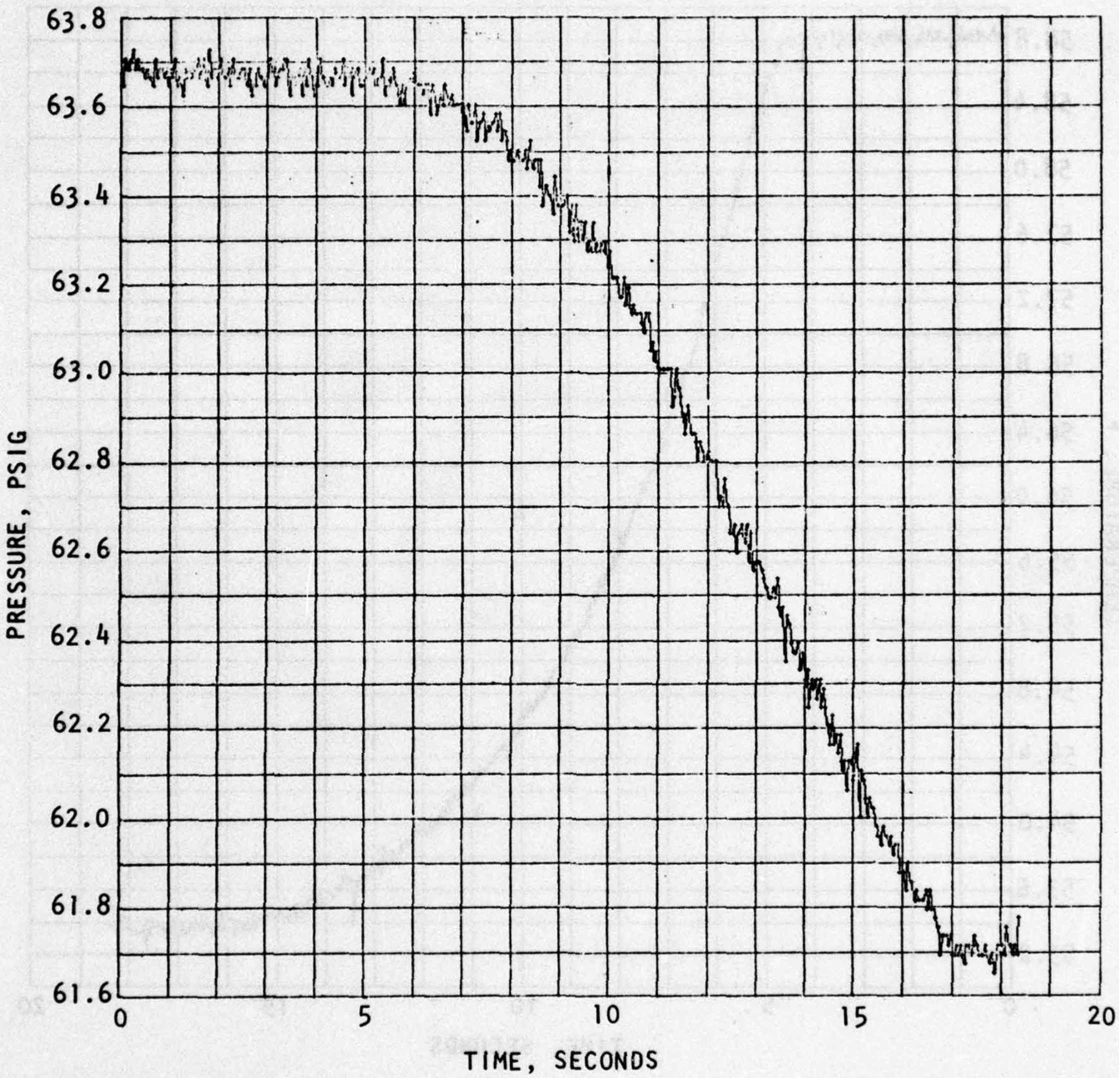


Figure 87. TEM-1 First Burn (Test 846-006) GN_2 Tank Temperature

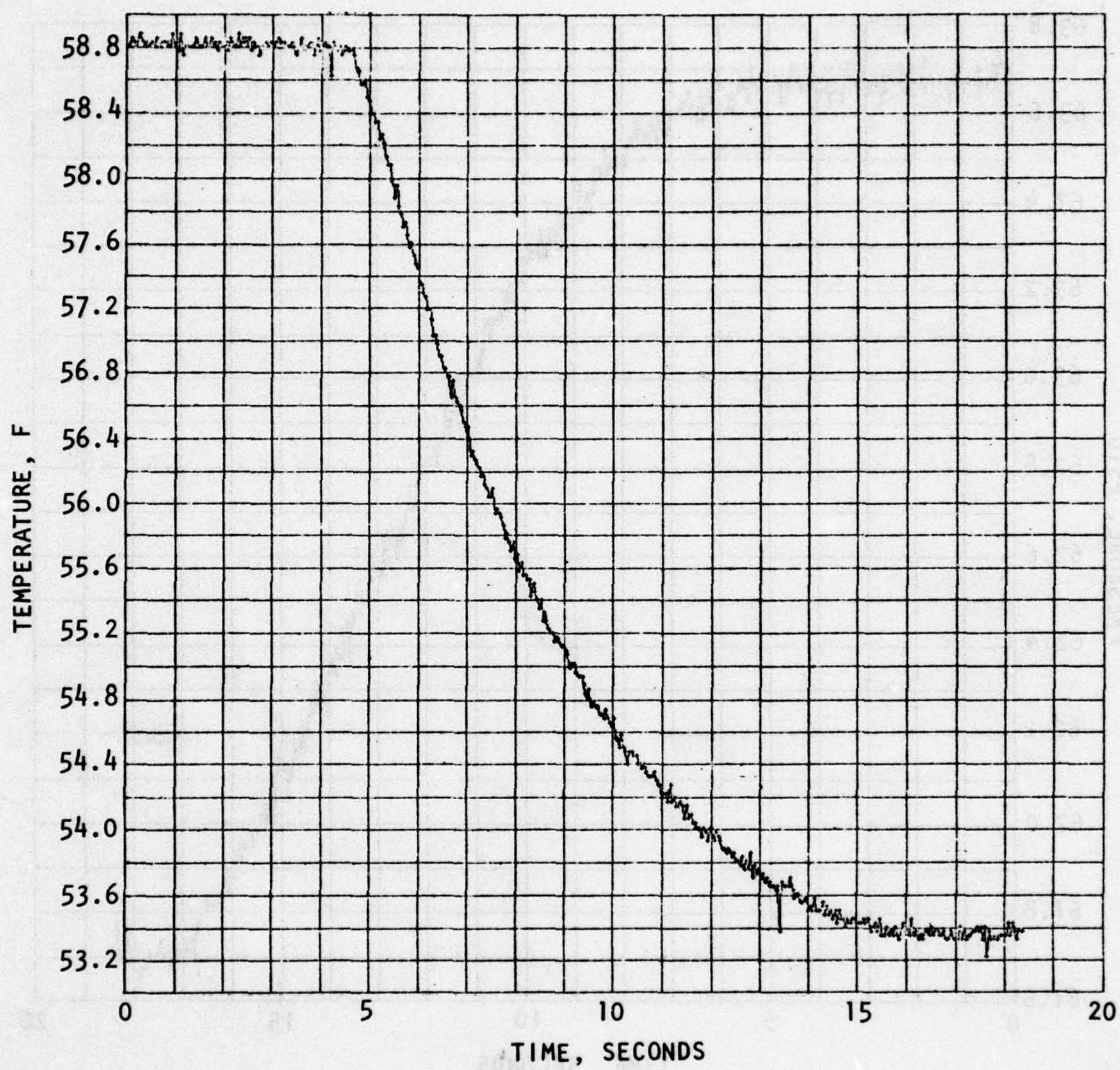


Figure 88. TEM-1 First Burn (Test 846-006) MMH Temperature

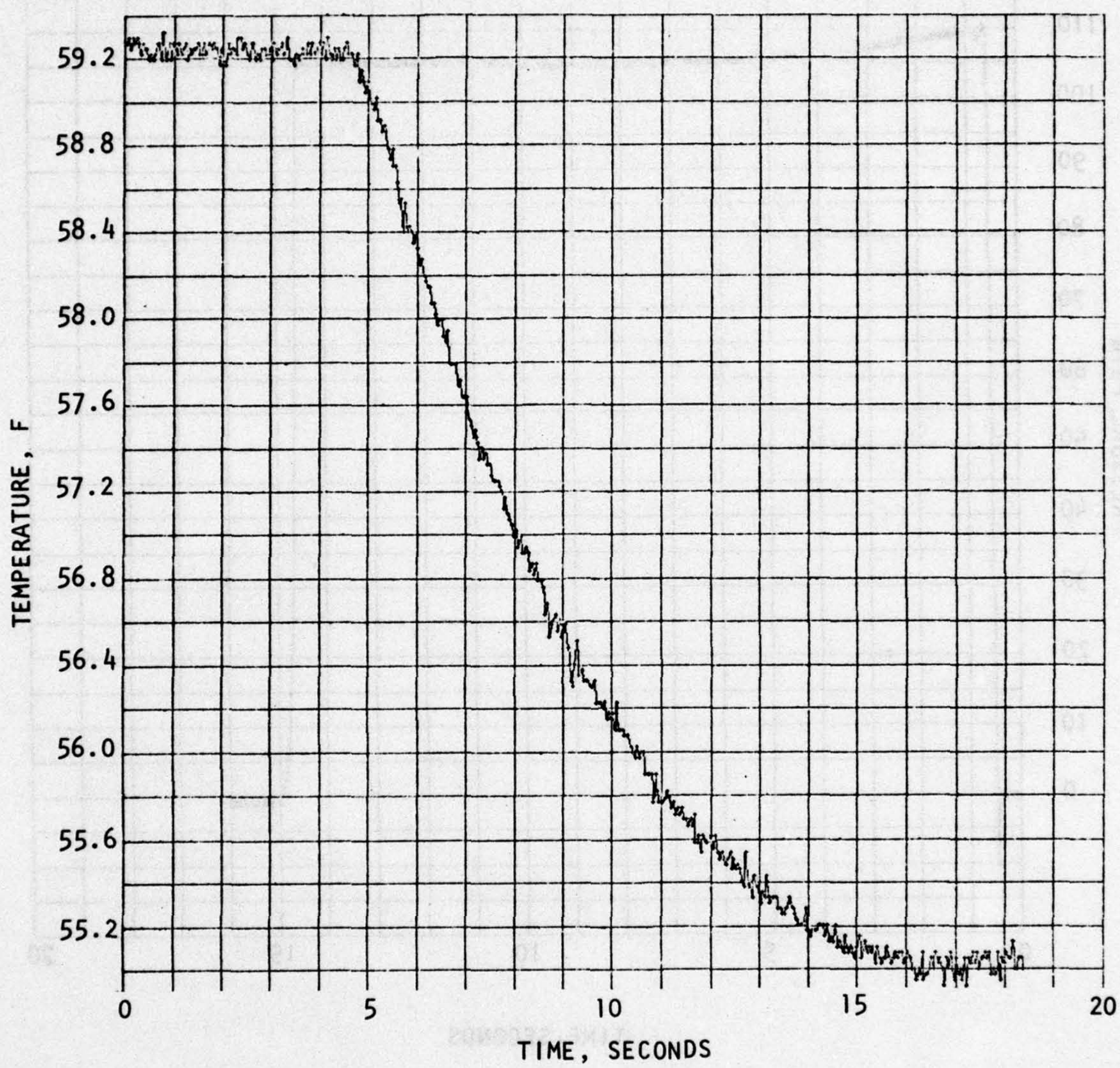


Figure 89. TEM-1 First Burn (Test 846-006) NTO Temperature

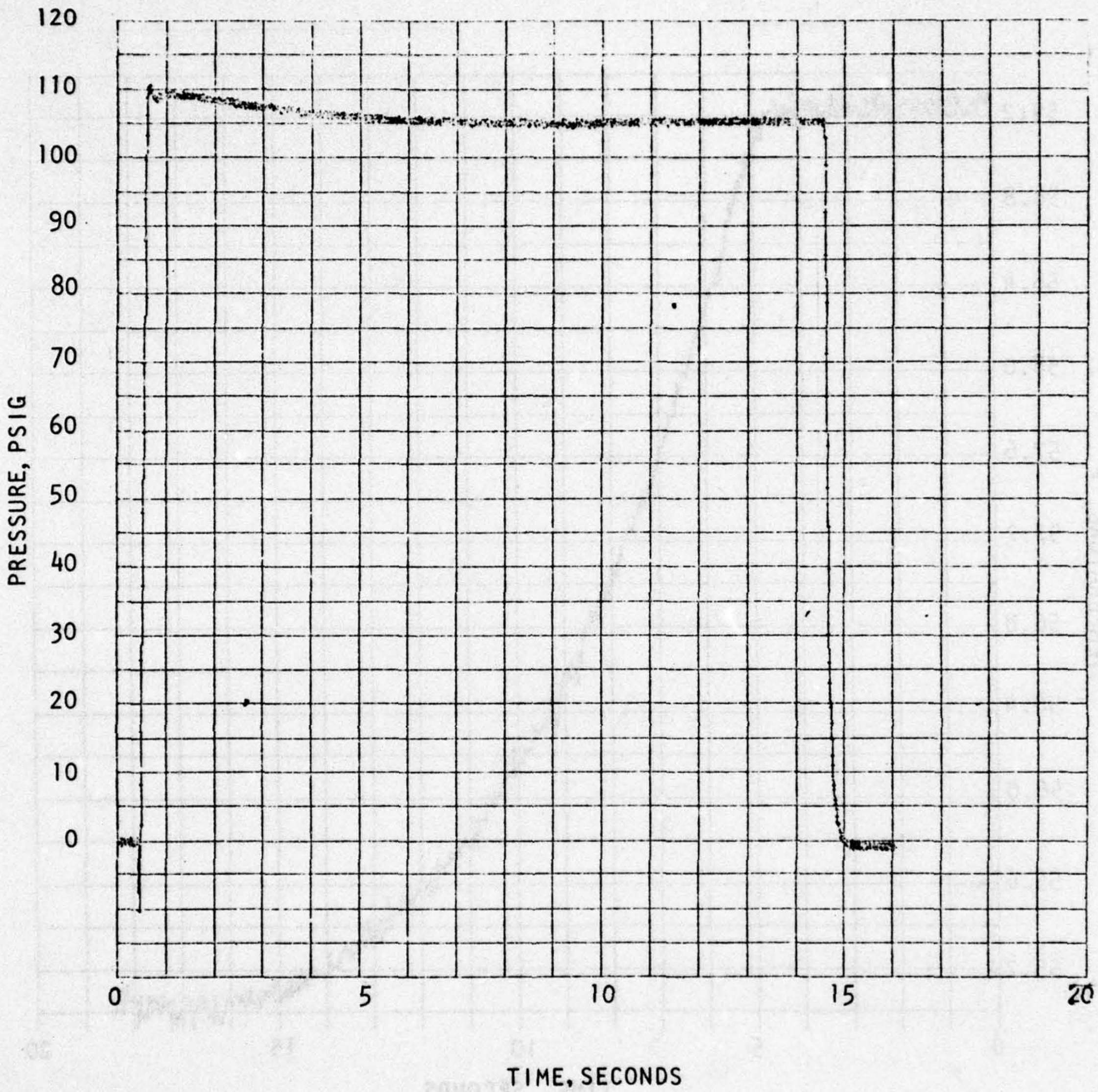


Figure 90. TEM-2 First Burn (Test 846-013) Chamber Pressure

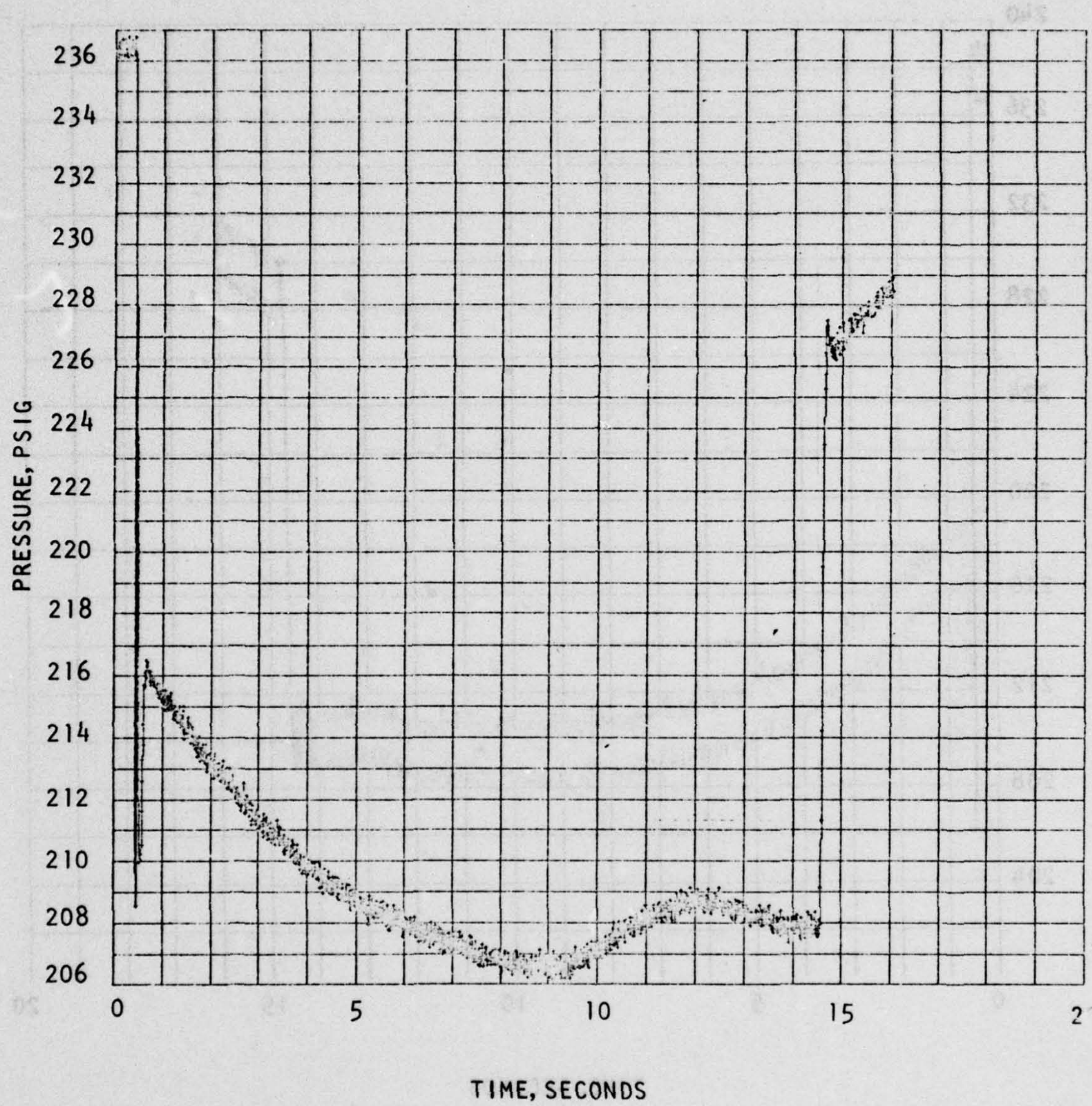


Figure 91. TEM-2 First Burn (Test 846-013) MMH Inlet Pressure

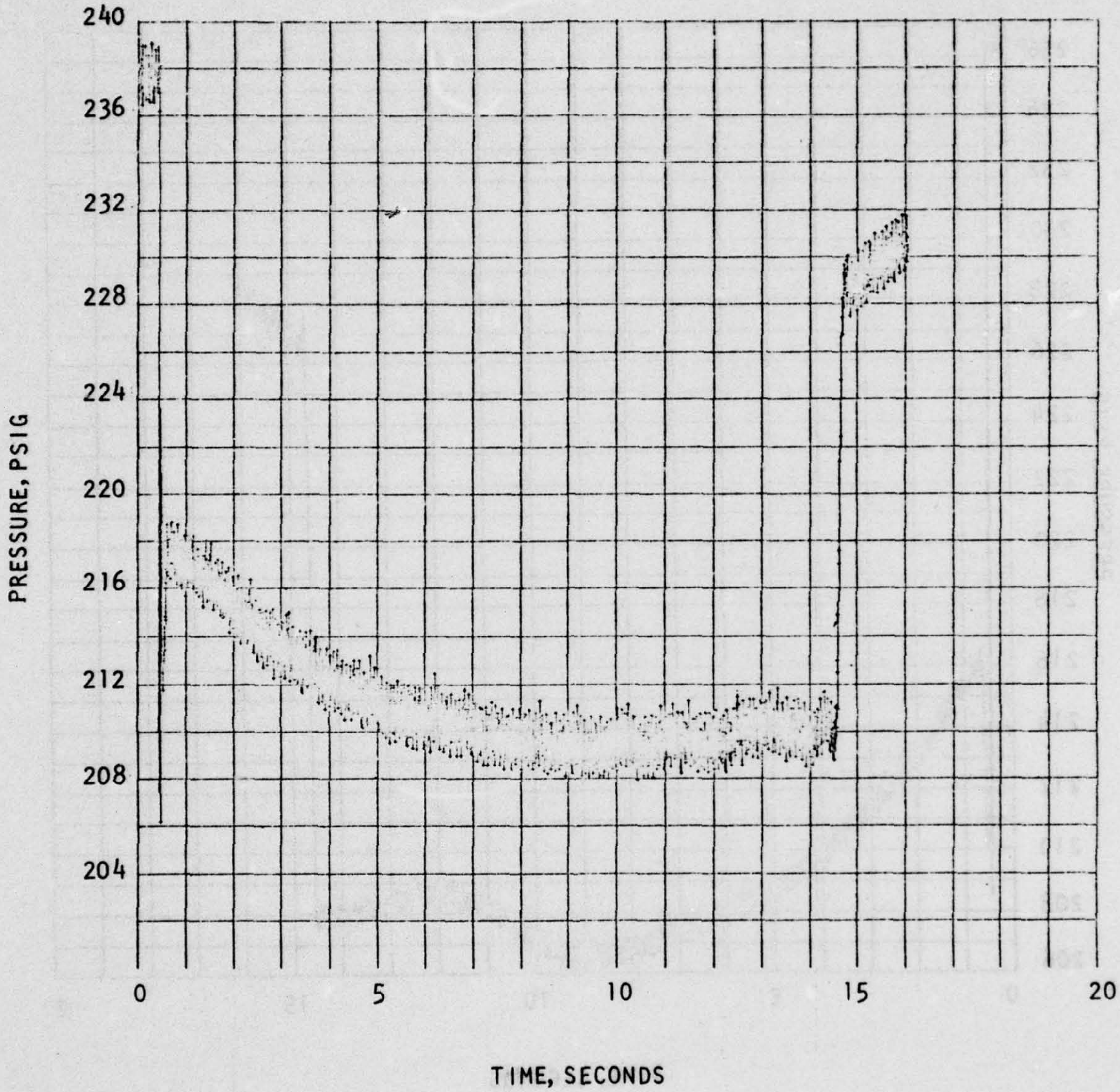


Figure 92. TEM-2 First Burn (Test 846-013) NTO Inlet Pressure

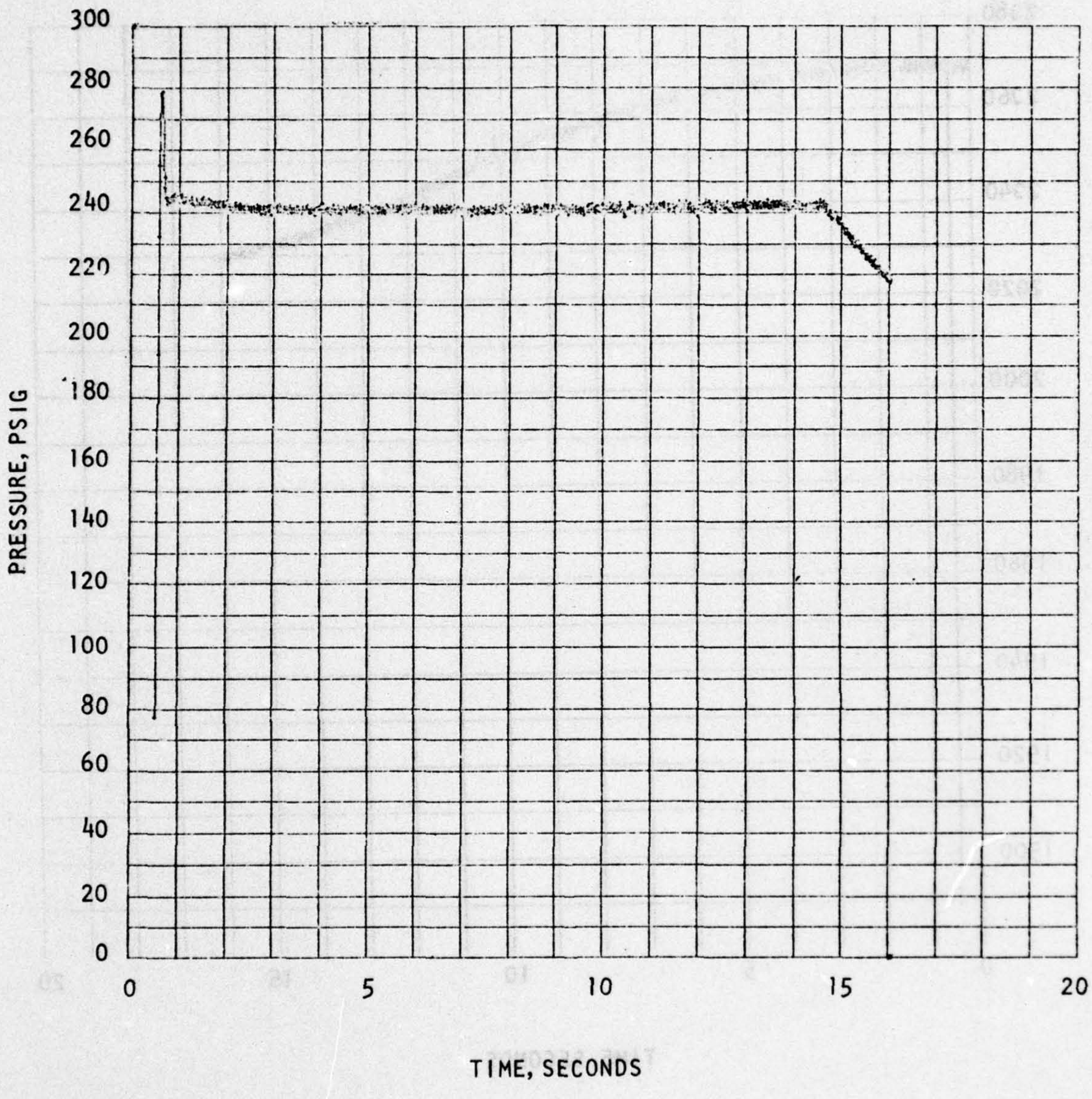


Figure 93. TEM-2 First Burn (Test 846-013)
Regulator Outlet Pressure

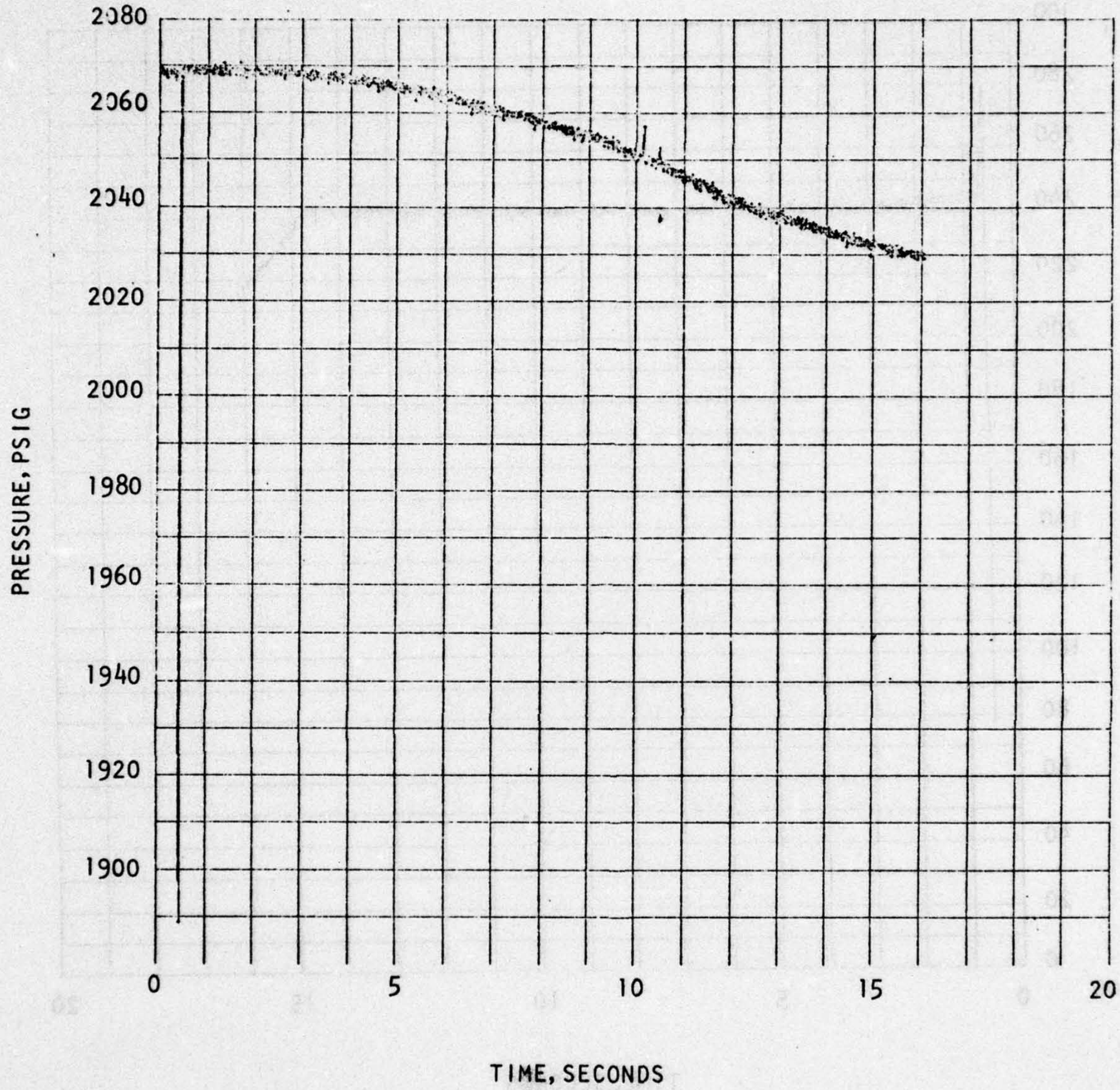


Figure 94. TEM-2 First Burn (Test 846-013) GN_2 Tank Pressure

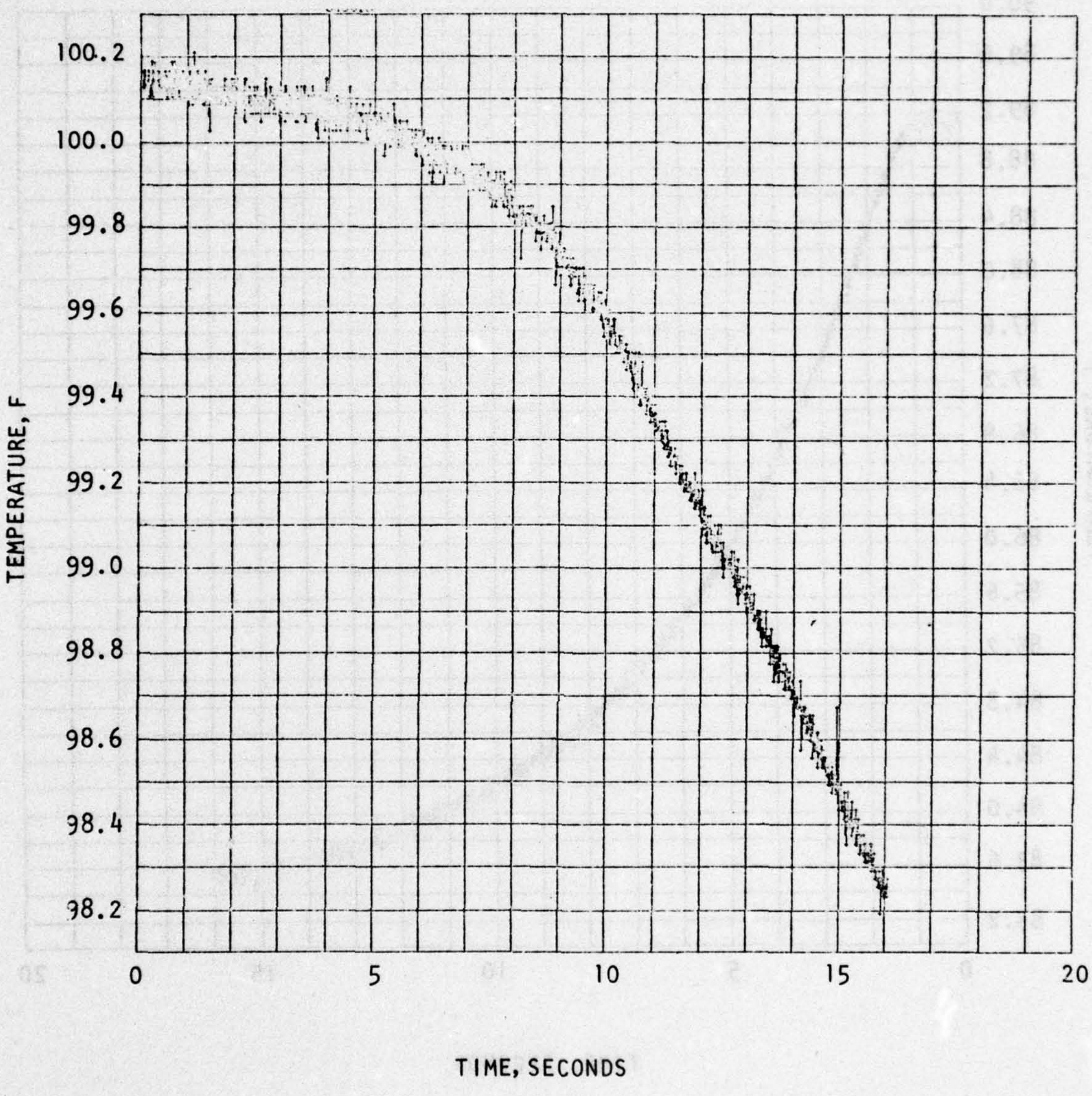


Figure 95. TEM-2 First Burn (Test 846-013)
GN_2 Tank Temperature

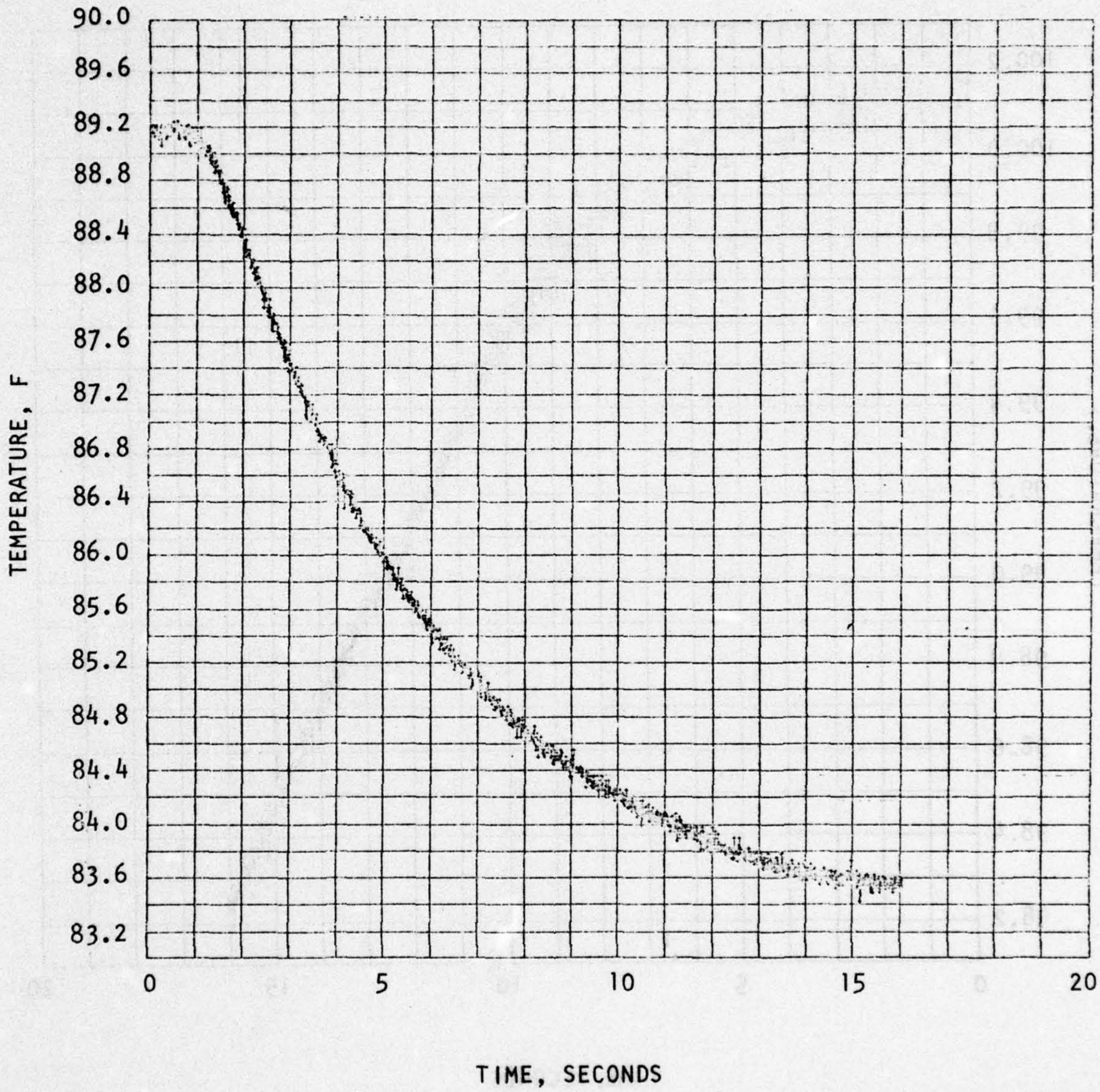


Figure 96. TEM-2 First Burn (Test 846-013) MMH Temperature

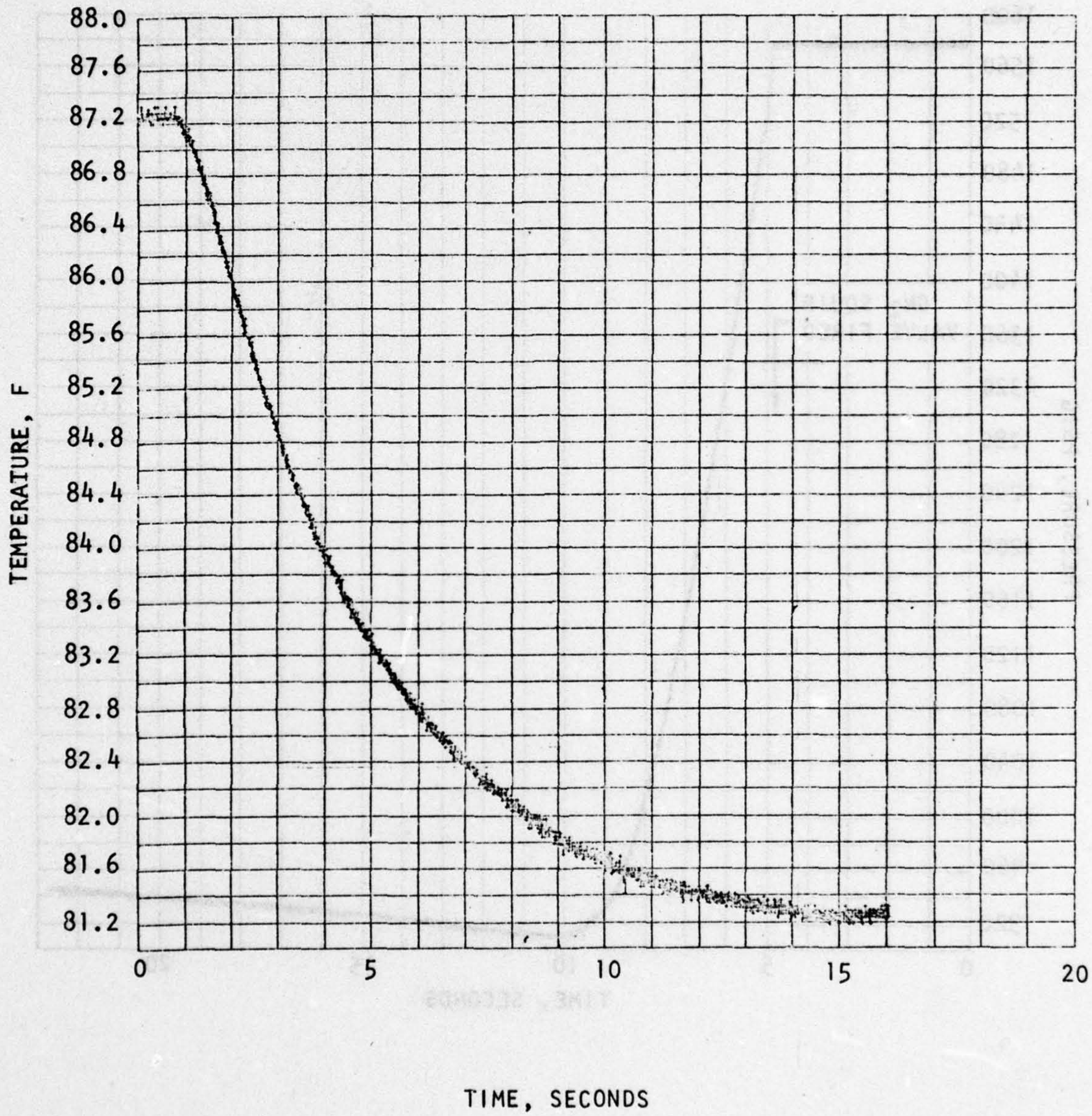


Figure 97. TEM-2 First Burn (Test 846-013) NTO Temperature

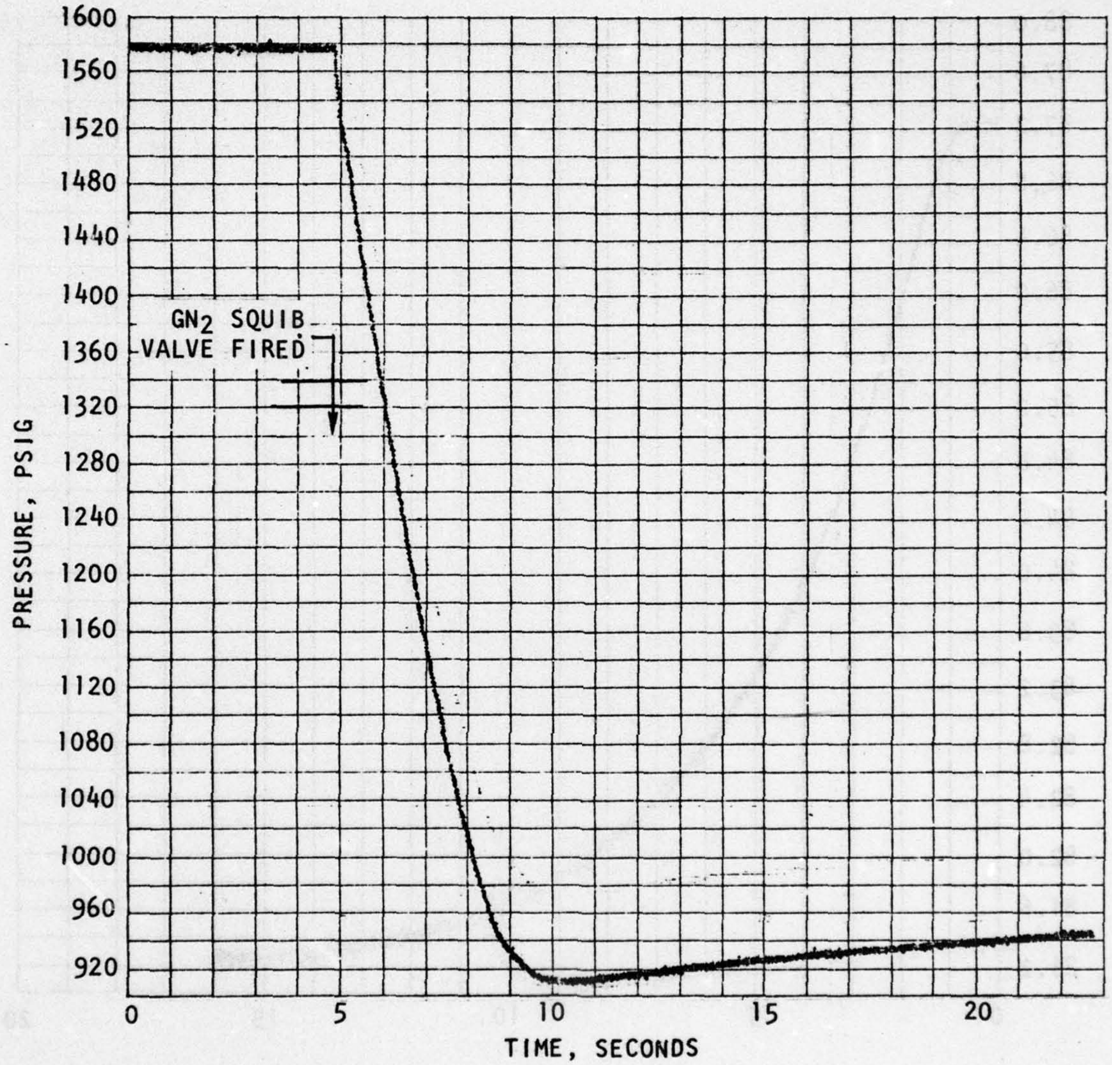


Figure 98. TEM-3 Pressurization Transient GN_2 Tank Pressure

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TARGET ENGINE SYSTEMS.(U)
APR 77 F04611-76-C-0001
UNCLASSIFIED RI/RD77-145 AFRPL-TR-77-52 NL

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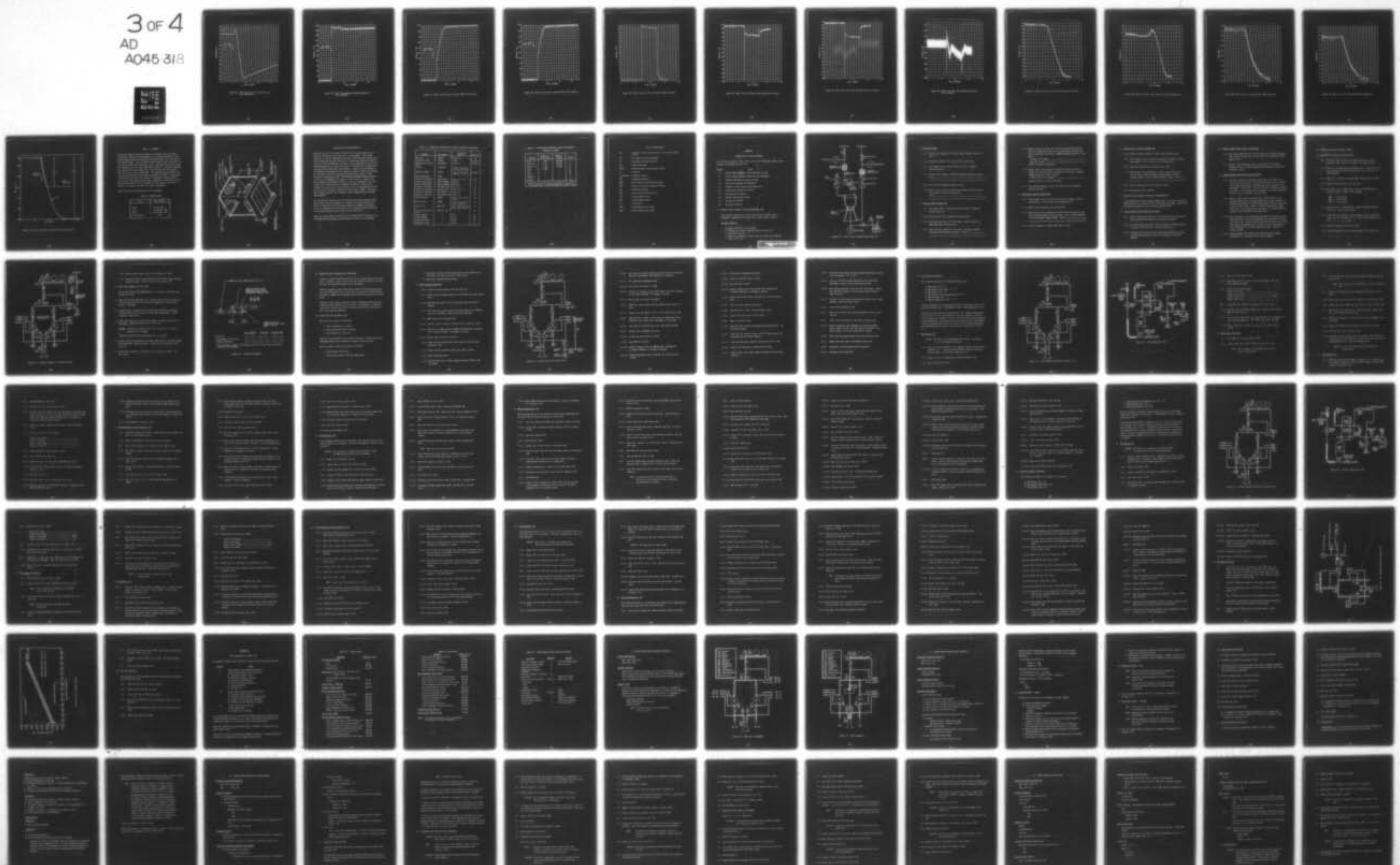
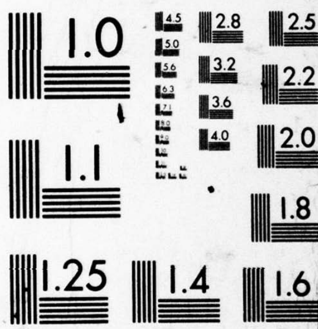




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

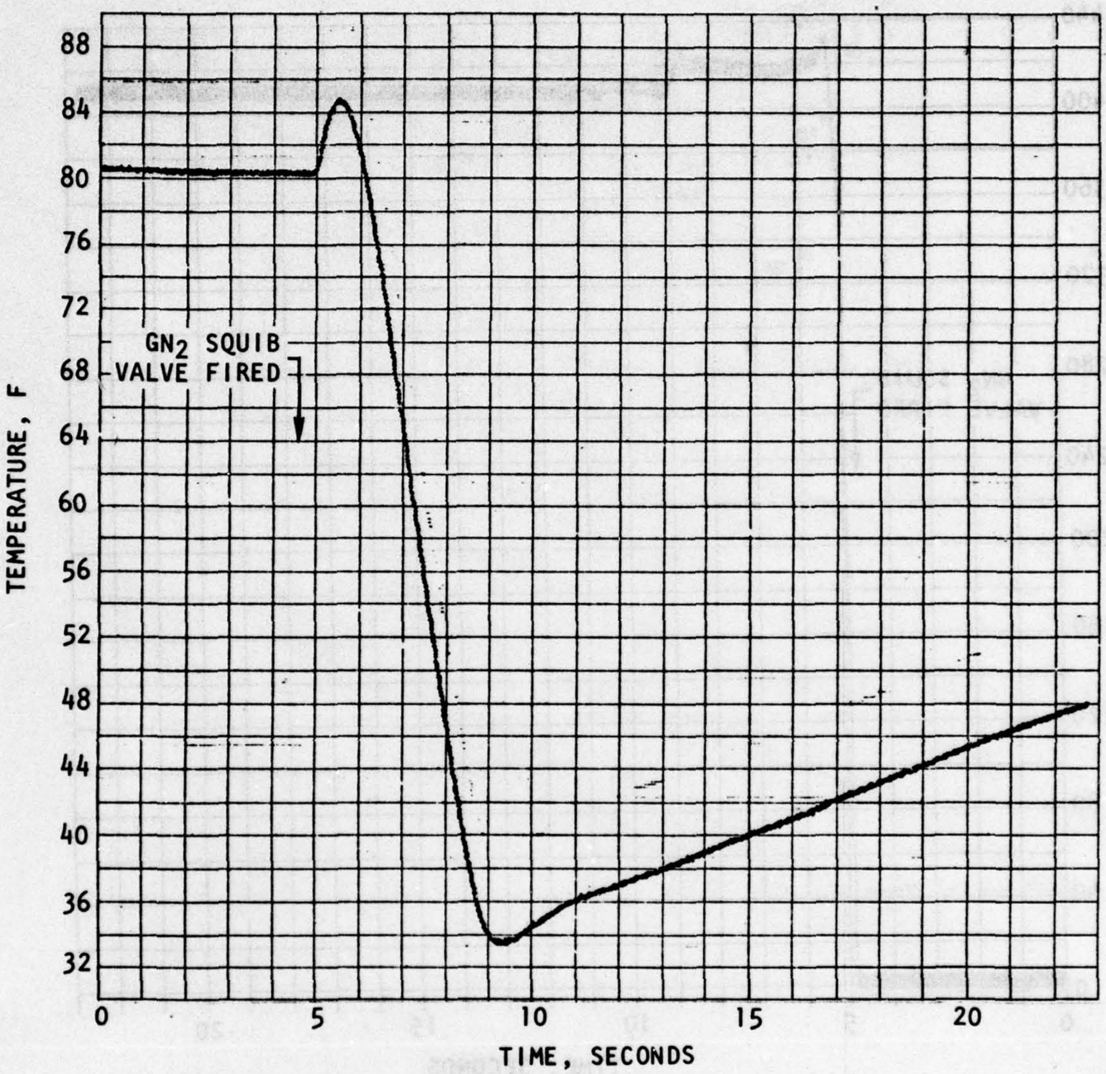


Figure 99. TEM-3 Pressurization Transient GN_2 Tank Temperature

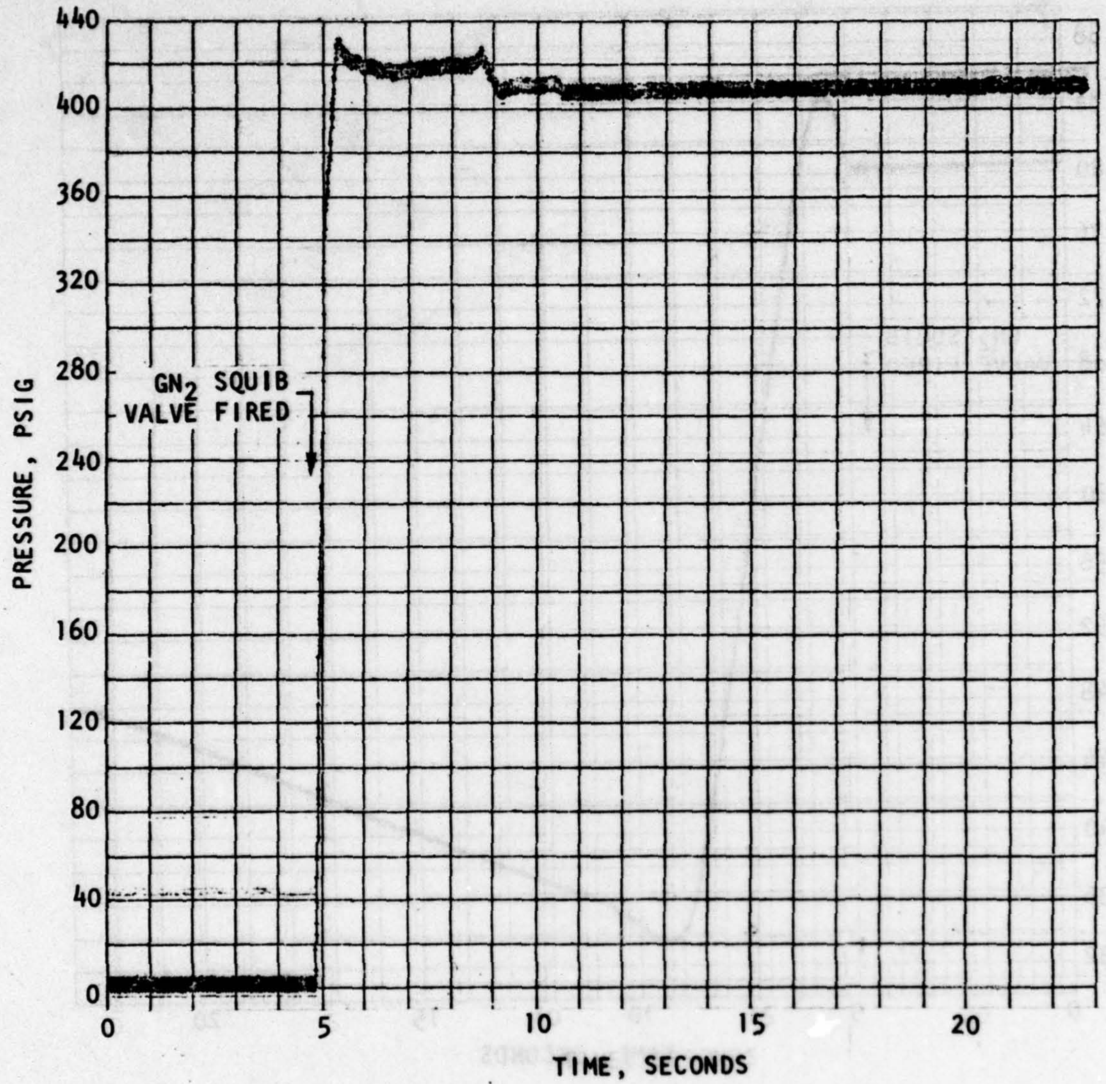


Figure 100. TEM-3 Pressurization Transient Regulator Outlet Pressure

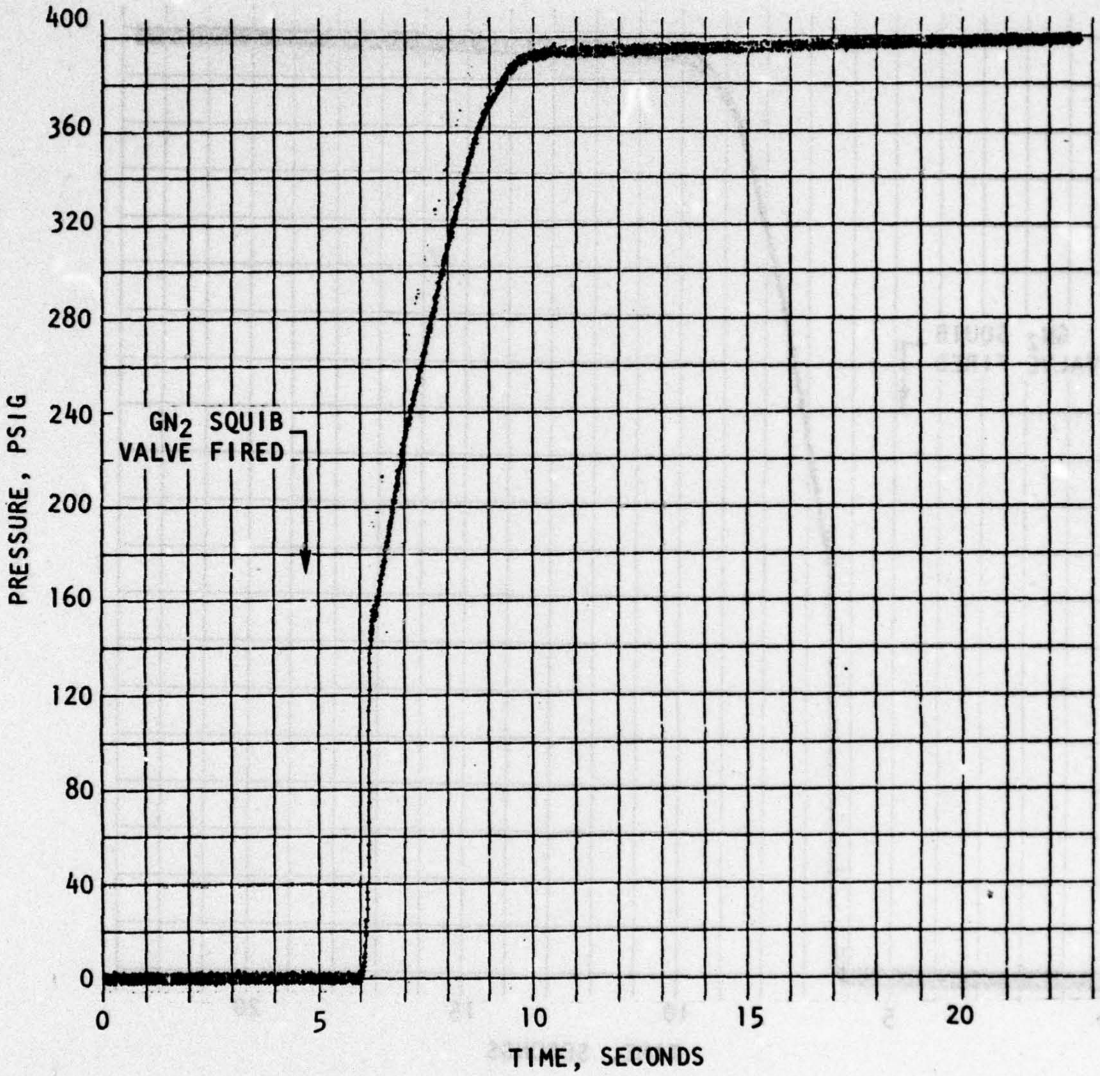


Figure 101. TEM-3 Pressurization Transient MMH Inlet Pressure

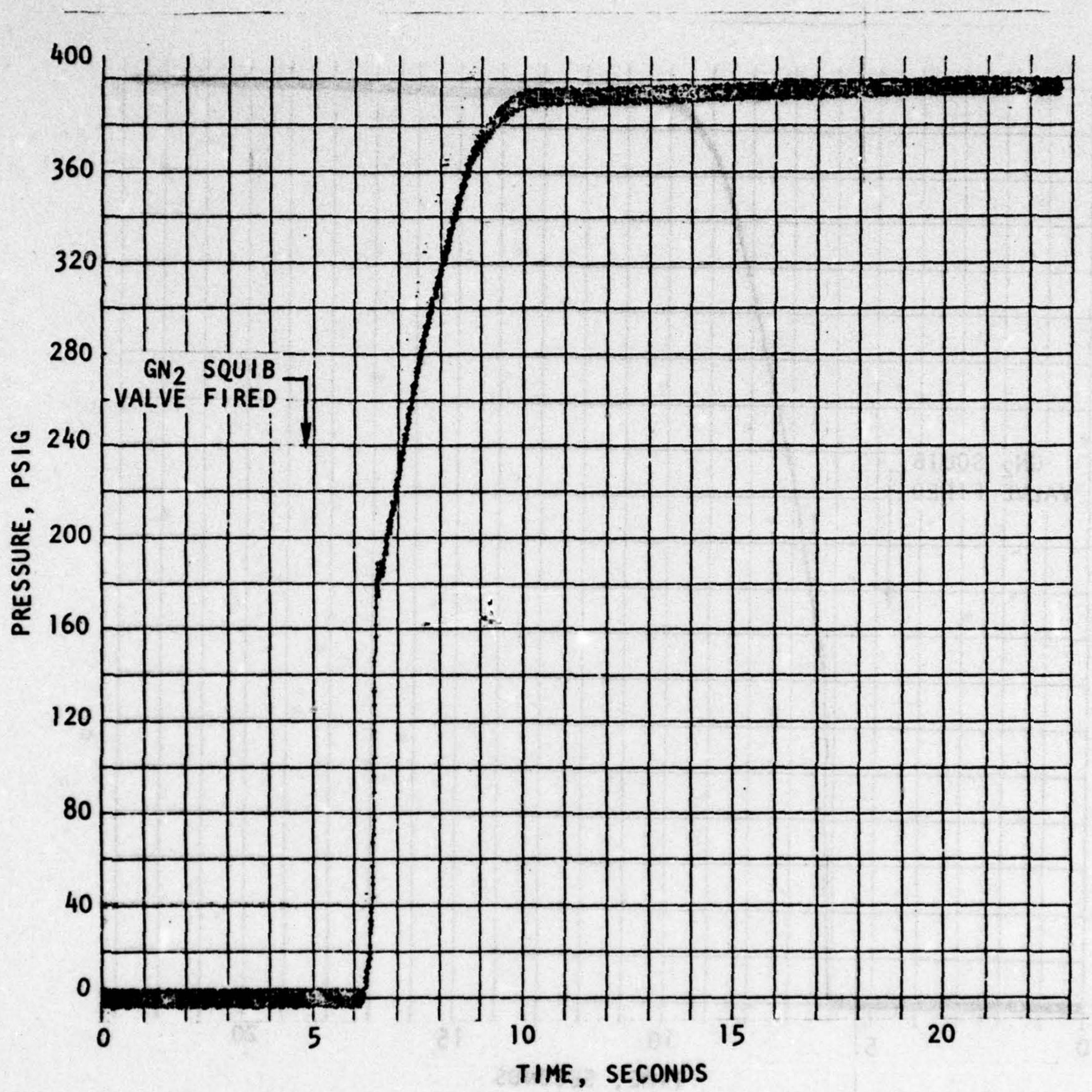


Figure 102. TEM-3 Pressurization Transient **NTO Inlet Pressure**

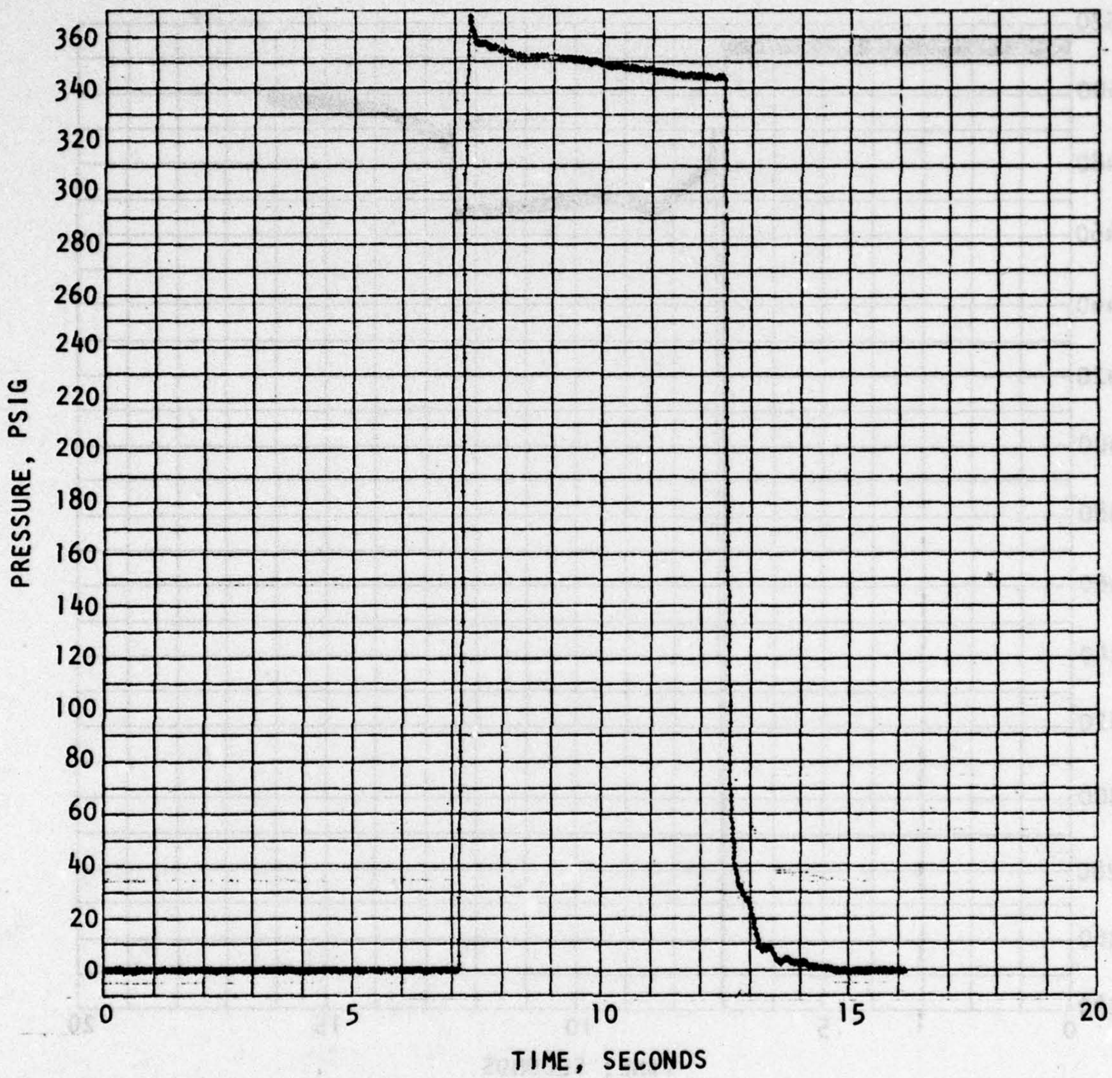


Figure 103. TEM-3 First Burn (Test 846-001) Chamber Pressure

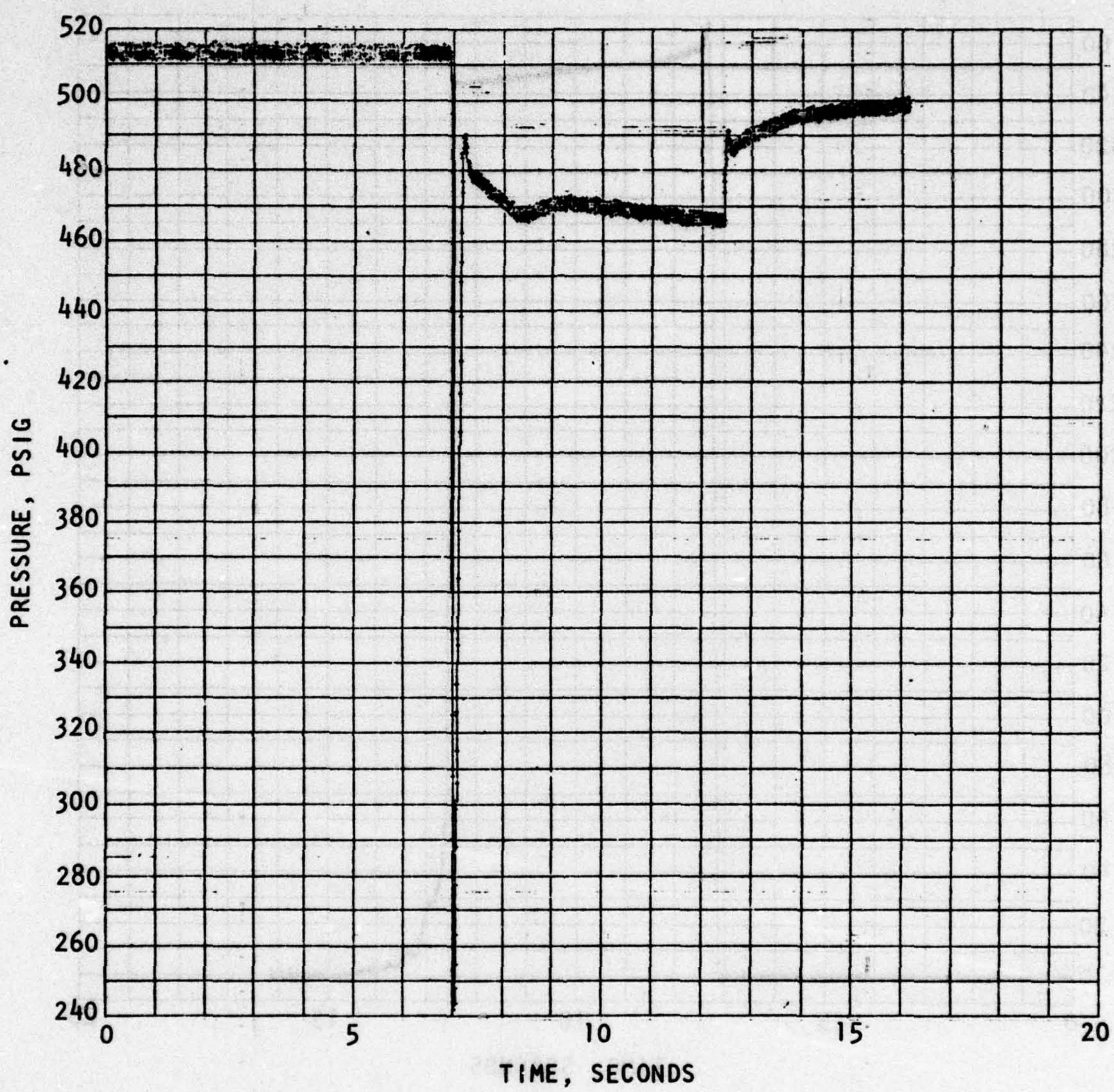


Figure 104. TEM-3 First Burn (Test 846-001) MMH Inlet Pressure

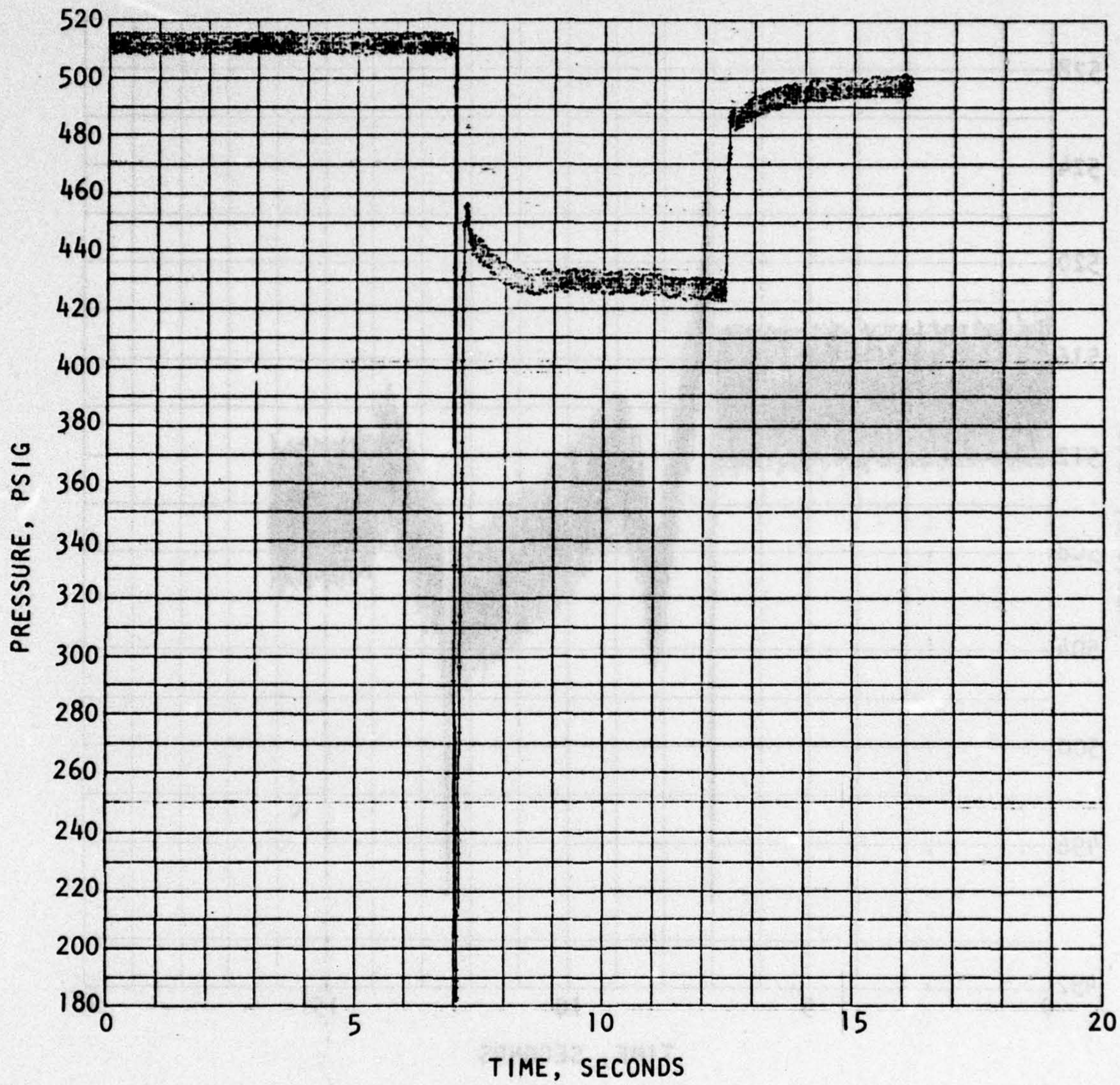


Figure 105. TEM-3 First Burn (Test 846-001) NTO Inlet Pressure

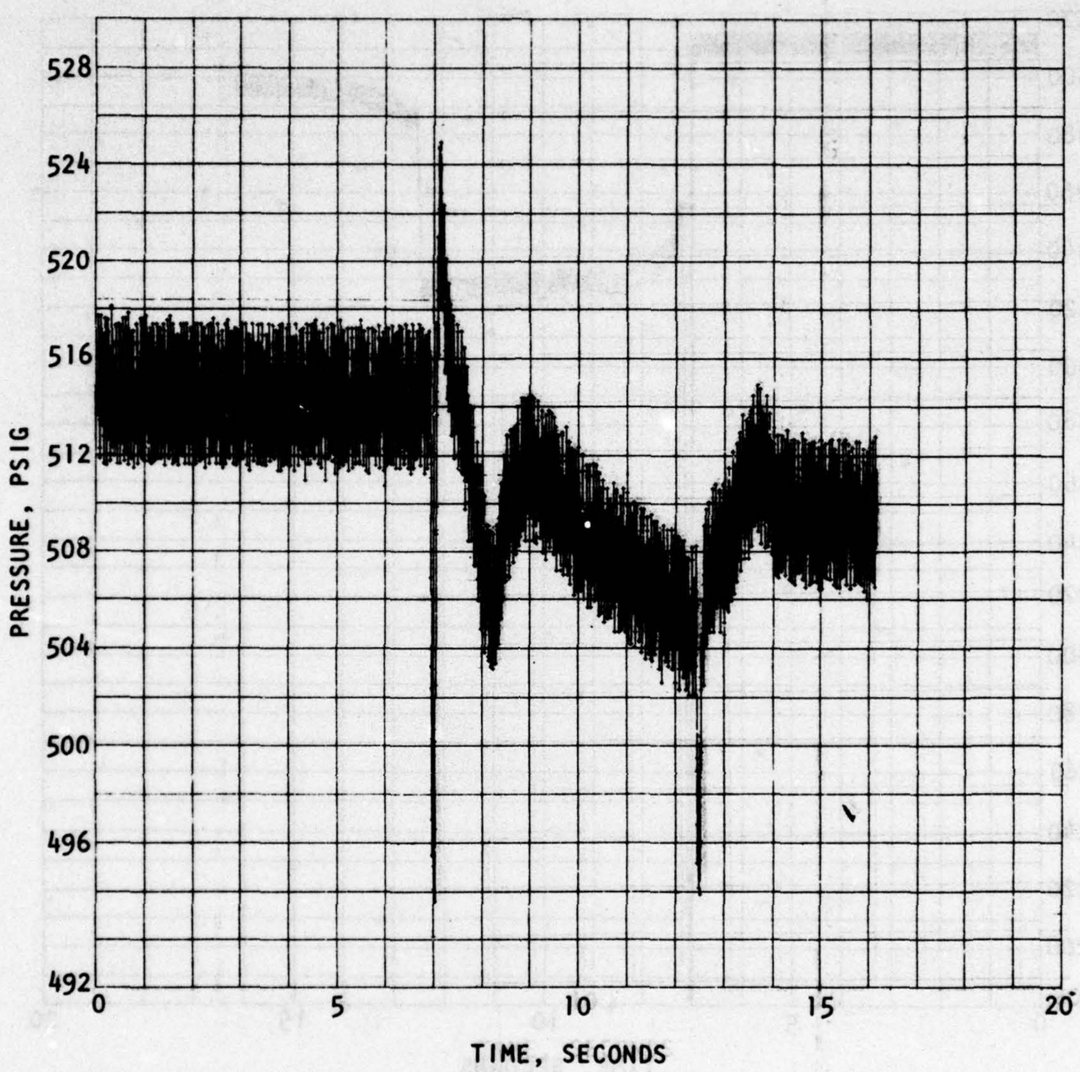


Figure 106. TEM-3 First Burn (Test 846-001) Regulator Outlet Pressure

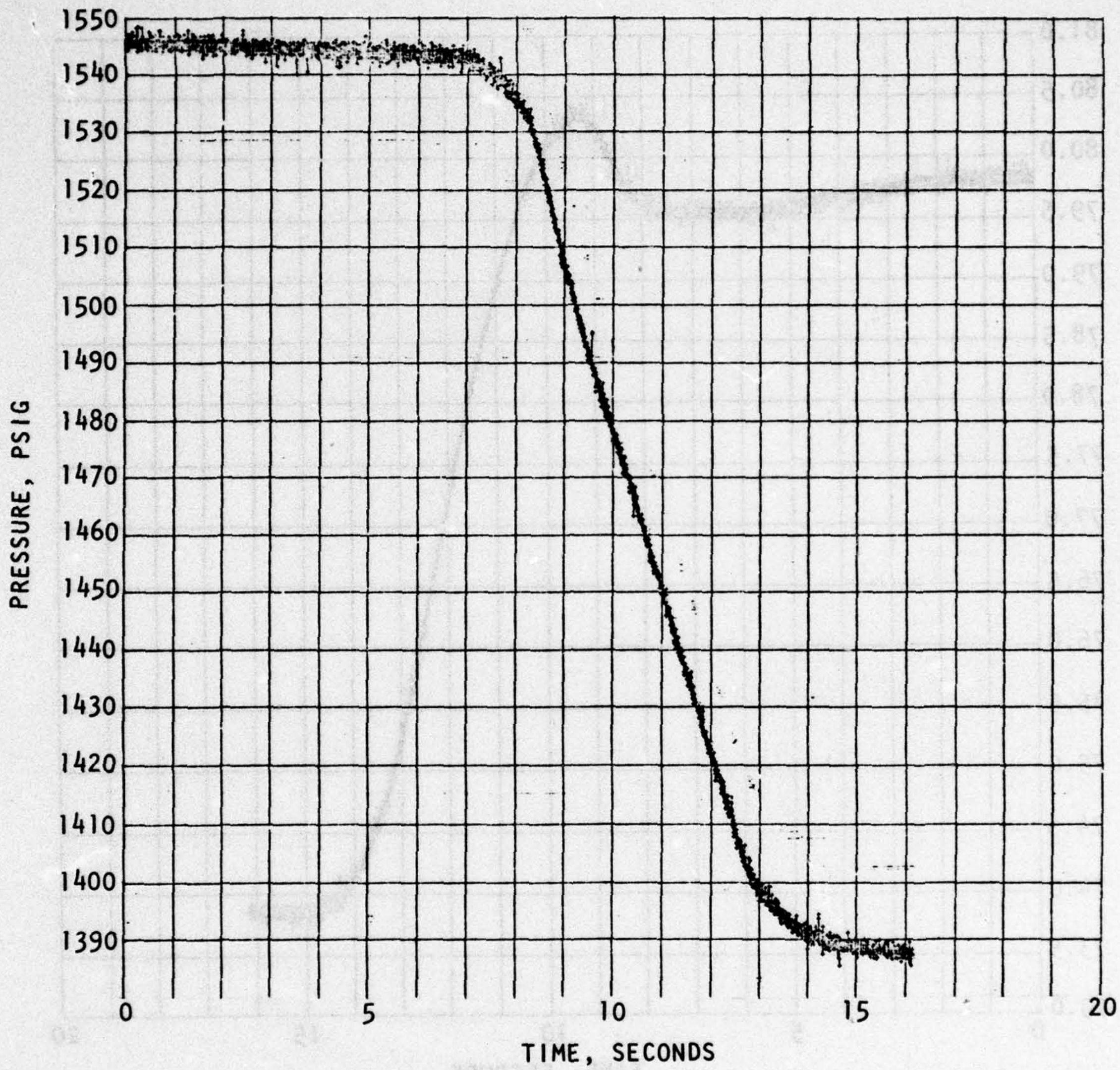


Figure 107. TEM-3 First Burn (Test 846-001) GN_2 Tank Pressure

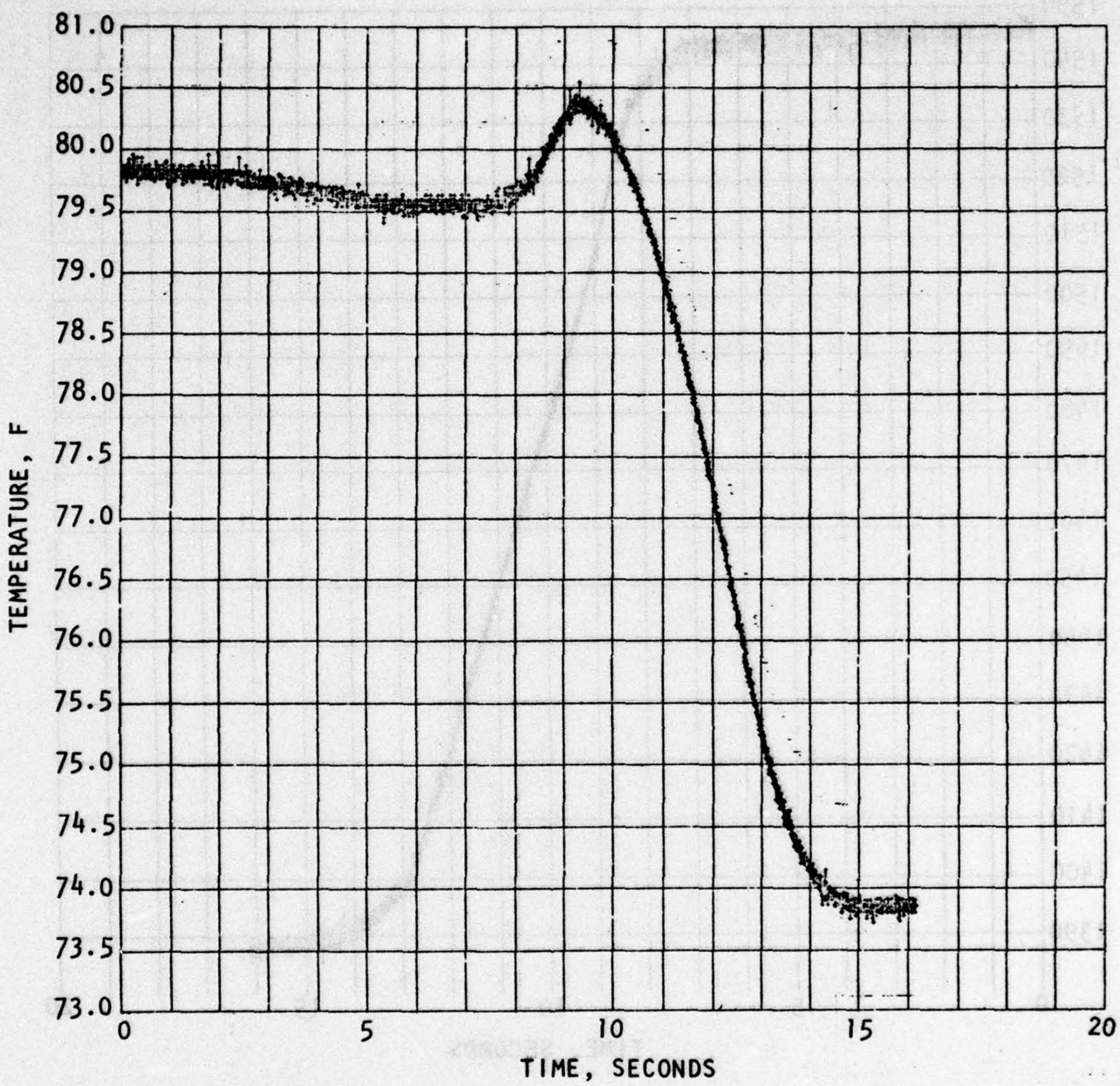


Figure 108. TEM-3 First Burn (Test 846-001) GN_2 Tank Temperature

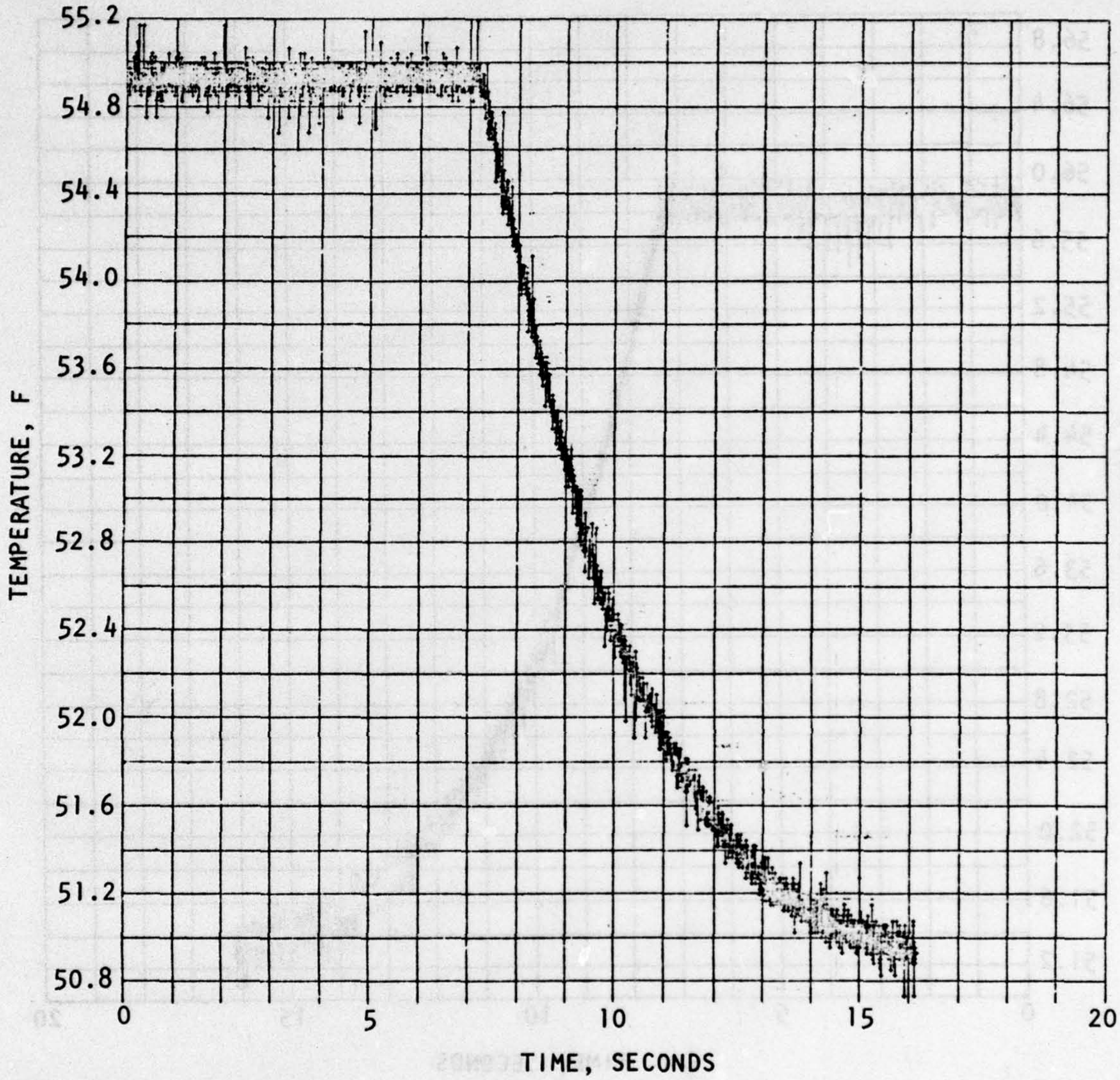


Figure 109. TEM-3 First Burn (Test 846-001) MMH Temperature

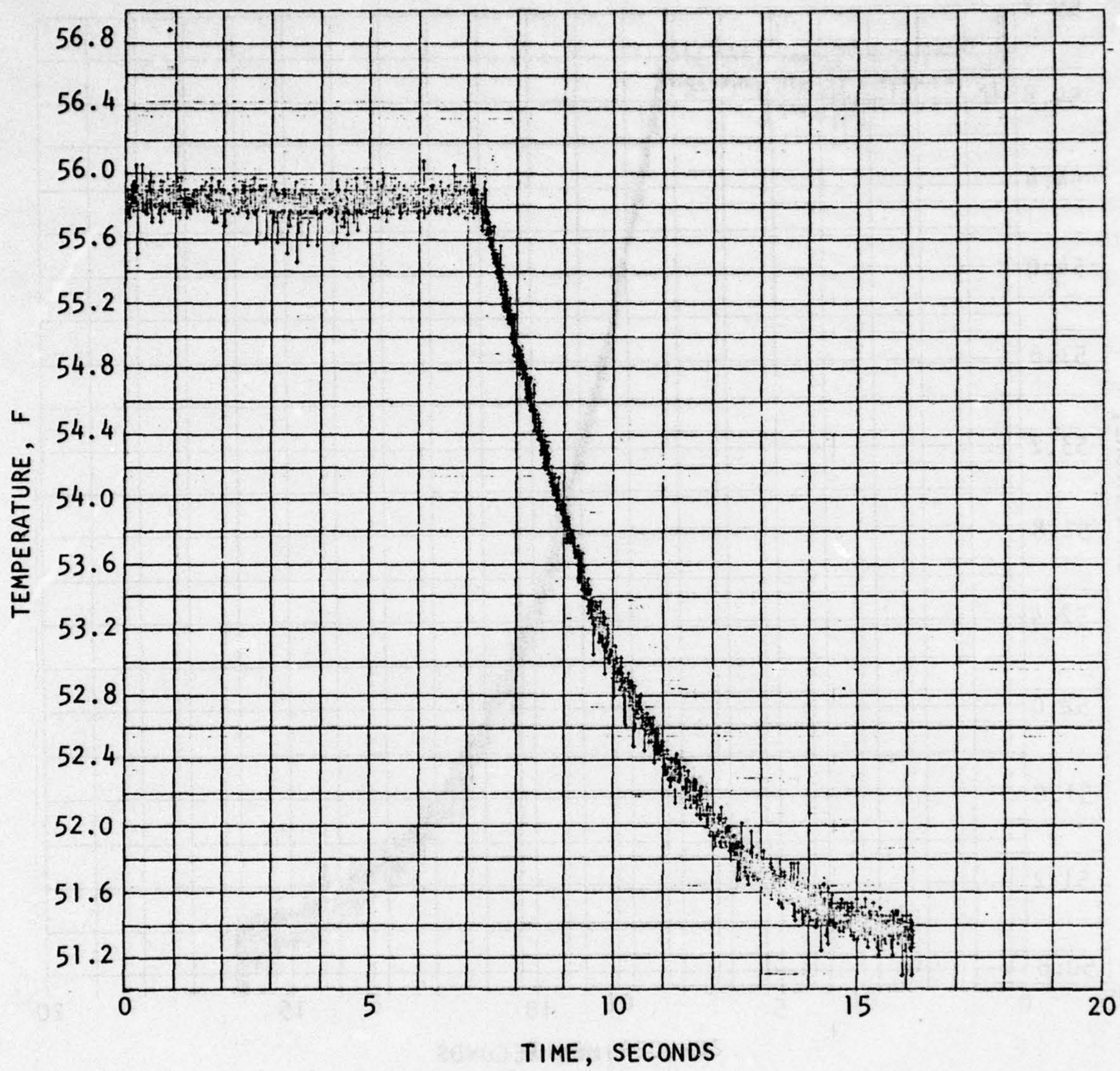


Figure 110. TEM-3 First Burn (Test 846-001) NTO Temperature

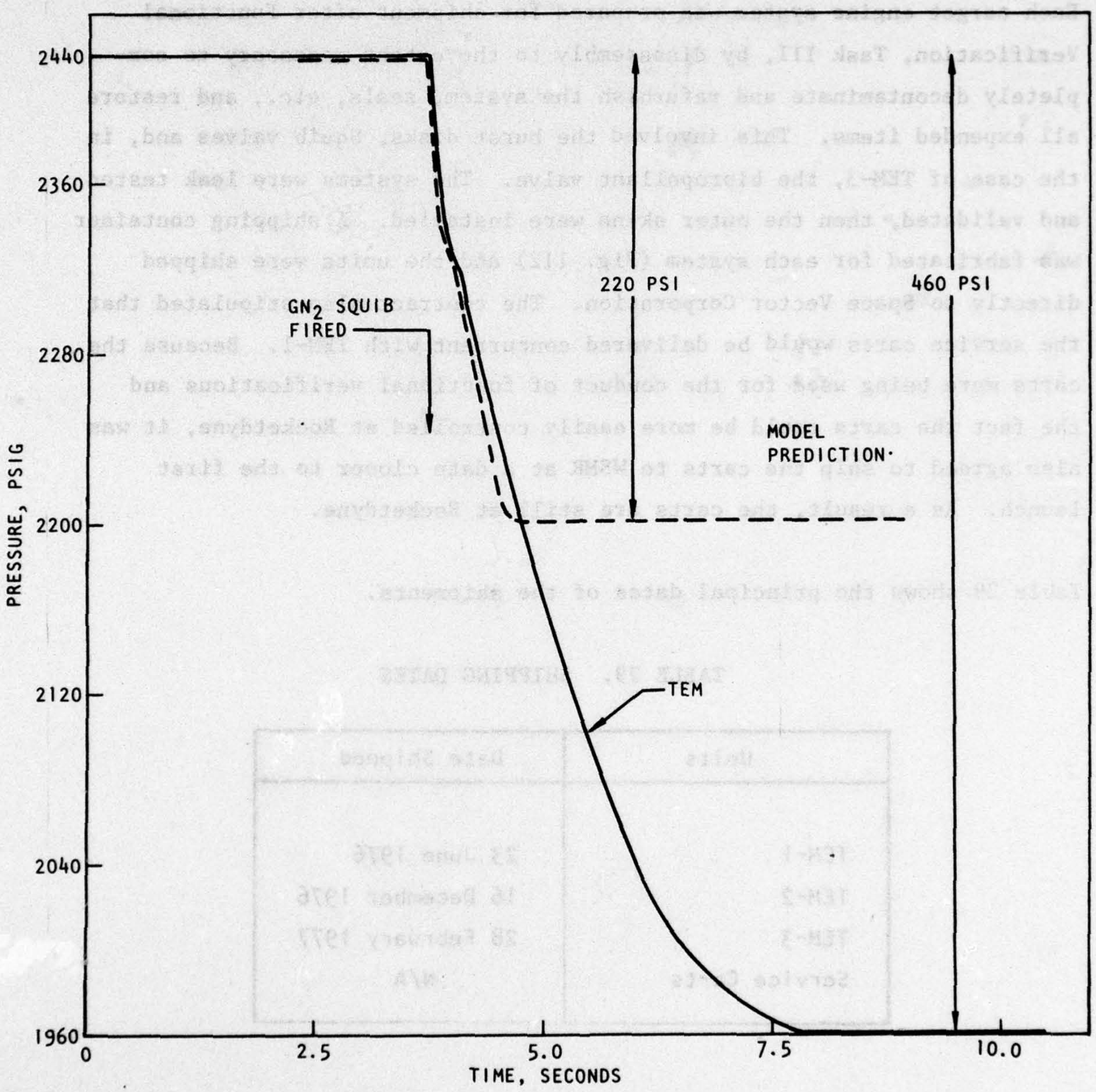


Figure 111. TEM-1 Pressurization Transient GN_2 Tank Pressure

TASK IV: SHIPMENT

Each target engine system was prepared for shipment after Functional Verification, Task III, by disassembly to the extent necessary to completely decontaminate and refurbish the system, seals, etc., and restore all expended items. This involved the burst disks, Squib valves and, in the case of TEM-3, the bipropellant valve. The systems were leak tested and validated, then the outer skins were installed. A shipping container was fabricated for each system (Fig. 112) and the units were shipped directly to Space Vector Corporation. The contract also stipulated that the service carts would be delivered concurrent with TEM-1. Because the carts were being used for the conduct of functional verifications and the fact the carts could be more easily controlled at Rocketdyne, it was also agreed to ship the carts to WSMR at a date closer to the first launch. As a result, the carts are still at Rocketdyne.

Table 29 shows the principal dates of the shipments.

TABLE 29. SHIPPING DATES

Units	Date Shipped
TEM-1	23 June 1976
TEM-2	16 December 1976
TEM-3	28 February 1977
Service Carts	N/A

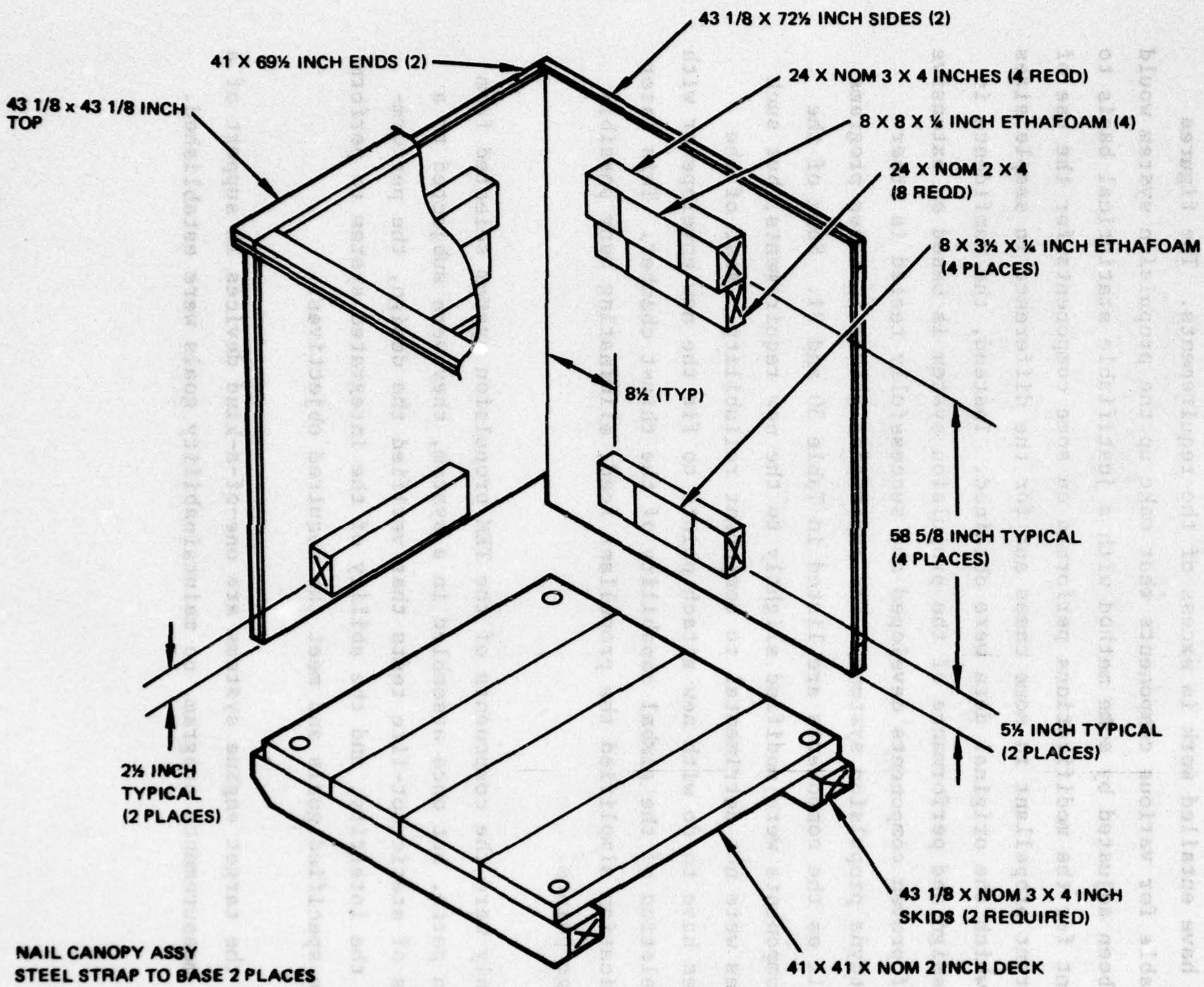


Figure 112. Shipping Container

RELIABILITY AND MAINTAINABILITY

Numerical values for reliability predictions are not provided since it would have entailed work in excess of the requirements. The figures available for various components that make up the propulsion system would have been adjusted by some method with a justifiable statistical basis to account for the modifications performed on some components for the use of different propellant in some cases and for the difference in sample sizes from which the original data were obtained. Instead, the confidence in the design and performance of the propulsion system is based on extensive use of proven components developed and successfully tested in other Rocketdyne propulsion systems. The experience gained in these programs as well as the components are listed in Table 30 and 31. Some of the TEM components were modified slightly to the new requirements, but such changes were not detrimental to component reliability. Most of the changes have to do with new attach points to fit the new envelope or with the deletion of the gimbal capability of the thrust chamber. This later modification simplified the propellant feed, eliminating many possible leakage points.

Not only were the components of the TEM propulsion system selected from proven parts, but once assembled in a system, they were subjected to a series of static hot-fire tests that verified the design, the performance, the integrity, and the ability of the integrated system to perform to the specified goals and meet the required objectives.

Since the target engine systems are one-of-a-kind devices in support of a plume measurements program, no maintainability goals were established.

TABLE 30. ACCUMULATED EXPERIENCE ON SELECTED ROCKETDYNE COMPONENTS

Component	Part Number	Experience Gained on	Modified
GN_2 Tank	307562	Saturn J-2	No
Propellant Tank	305477	Atlas	Slightly
Explosive Activated Valve	NA5-260180	Saturn H-1	Slightly
Filters	14204-610	Similar type used on Atlas and RS-27	--
Regulator (GN_2)	553700	Atlas, Thor, RS-27 Redstone, Jupiter	Slightly
Burst Diaphragm	10523		
Temperature Sensors	NA5-27215T3	Saturn F-1, J-2	No
Signal Conditioner	Model 510BH64	New Part	--
Signal Conditioner	Model 510BH65	New Part	--
Pressure Transducer	NA5-27412-T35T	Saturn F-1	No
Pressure Transducer	NA5-27412-T5T	Saturn F-1, J-2	No
Pressure Transducer	NA5-27316-T2	Saturn F-1	No
Pressure Transducer	NA5-247440-T10T	Saturn F-1	No
4-Way Solenoid	555695	Atlas, Thor, RS-27, J-Thor	No
Relief Valve	550084	Atlas, Thor, RS-27, J-Thor, Redstone	No
Check Valve	280T1-8TT	Basic Design Used on Atlas, Thor, RS-27	No
Fill, Drain & Vent Valve	1831-16, -15	--	No
Thrust Chamber	--	RS-14	No
Thrust Chamber	--	Atlas	Yes
Propellant Valve	--	RS-14	No
Propellant Valve	--	Atlas	No

TABLE 31. ACCUMULATED EXPERIENCE GAINED ON ROCKETDYNE PROPULSION SYSTEMS

Systems	Number of Static Tests	Number of Seconds	Flights
Saturn F-1	3,248	280,000	13
Saturn H-1	6,417	474,000	19
Saturn J-2	4,422	495,000	22
Atlas	11,300	*	427
Thor	*	*	366
RS-27	*	*	34
Redstone	*	*	72
Jupiter	*	*	33

*Numerical values not readily available but are known to be substantial in both magnitude and calendar time.

LIST OF ABBREVIATIONS

ACS	=	Attitude Control Stage attached to the target engine system
GFE	=	Government Furnished Equipment
GFP	=	Government Furnished Property
GN_2	=	Gaseous Nitrogen
HPTEM	=	High Performance Target Engine Module
IR	=	Infrared
Isopropanol	=	Isopropyl alcohol
MMH	=	Monomethylhydrazine
MSMP	=	Multi Spectral Measurements Program
NTIS	=	National Technical Information Service
NTO	=	Nitrogen Tetroxide
SSFL	=	Santa Susana Field Laboratory
TES	=	Target Engine Safety
TEM	=	Target Engine Module
UV	=	Ultraviolet
VAFB	=	Vandenberg Air Force Base
WSMR	=	White Sands Missile Range

APPENDIX A

TARGET ENGINE SYSTEM PROCEDURES

The following procedures, which evolved during the development phase of this program, are intended for field use.

Section	Title
1.0	Vernier Engine Assembly--Leak and Functional Test
2.0	Vernier Engine Assembly--Propellant Decontamination
3.0	Pneumatic Regulator--Pressure Setting
4.0	Squib Valve Checkout (P/N TEP 1025)
5.0	Transducer Check (Pressure and Temperature)
6.0	System Leak and Functional Tests
7.0	Fuel Handling Procedures
8.0	Oxidizer Handling Procedures
9.0	GN_2 Charge Procedure
10.0	GN_2 Dump Procedures

1.0 VERNIER ENGINE ASSEMBLY--LEAK AND FUNCTIONAL TEST

This procedure applies only after vernier engine assembly rework or disassembly (subassembly not installed in target engine system).

Equipment Required

- Atlas G3024 Throat Plug (vented)
- 150-psig GN_2 source, filtered (25 micron absolute)
- Leak check solution
- Valves (2), gages (2), filter, leak rate device and plumbing shown in Fig. A-1.

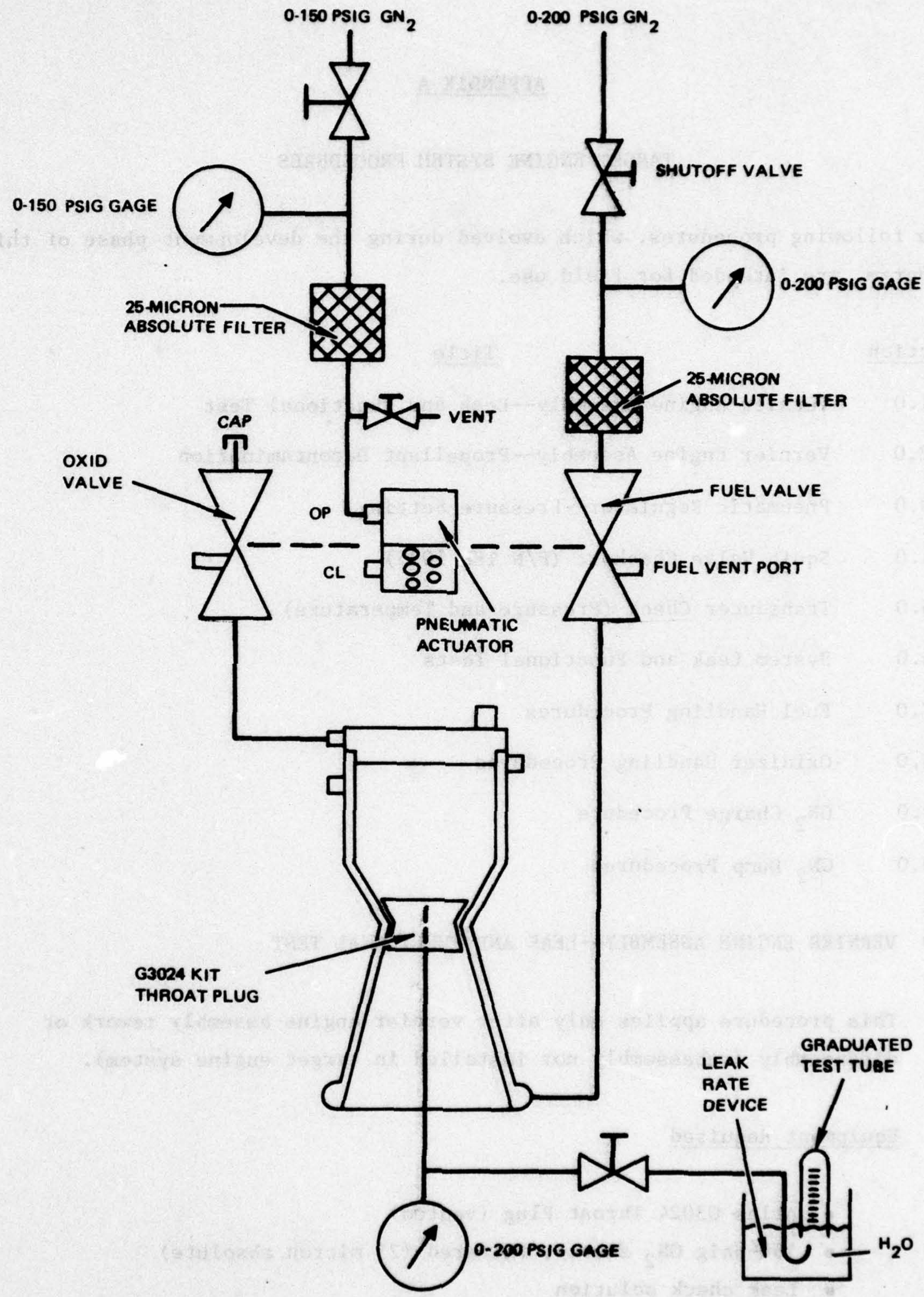


Figure A-1. Vernier Engine Assembly Functional Test

1.1 Valve Functional

1.1.1 Connect test equipment to vernier engine assembly as shown in Fig. A-1.

1.1.2 Pressurize engine to 10 ±5 psig at fuel valve inlet.

1.1.3 Open engine valve by applying 100 ±10 psig to pneumatic actuator open port.

1.1.4 Monitor valve opening by observing bubbles in leak rate device. Record ____

____

1.1.5 Vent off valve opening pressure to zero.

1.1.6 Monitor valve closing by observing <u>no</u> bubbles in H_2O container. Valve should close with spring force.
Record ____

____

1.3 Engine Assembly Leakage Test

1.2.1 Open engine valve by applying 100 ±10 psig GN_2 to pneumatic actuator open port.

1.2.2 Close facility valve downstream of throat plug.

1.2.3 Pressurize fuel inlet to 150 ±10 psig. Monitor pressure on gage downstream of throat plug.

1.2.4 Apply leak test compound to all joints, fittings, threaded connectors and potential leak paths. Record ____________________

____

1.2.5 Remove closures from fuel vent port and oxidizer vent port and check for leakage past shaft seals by monitoring with leak rate device connected to vent ports. Maximum leakage allowed is 5 scim. Record:

Oxidizer Vent Leakage ______________________

Fuel Vent Leakage ______________________

Install closures at vent ports.

1.2.6 Remove closure from pneumatic actuator close port and monitor leakage with leak rate device connected to close port. Maximum leakage allowed is 5 scim. Record:

Actuator Close Port Leakage______________________

Install closure at actuator close port.

1.2.7 Vent system pressures to zero, fuel valve inlet and pneumatic actuator open port.

1.3 <u>Fuel Valve Internal Leakage Test</u>

1.3.1 Verify engine valve as closed by venting off penumatic actuator open pressure. Valve should close by spring force.

1.3.2 Apply 150 ±10 psig GN_2 at fuel valve inlet.

1.3.3 Open facility valve downstream of throat plug and check for fuel valve internal leakage in H_2O container. Wait 5 minutes minimum; 5 scim is maximum leakage allowed. Record ______________________

____

1.3.4 Vent off pressure to engine valve inlet to zero.

1.4 Oxidizer Valve Internal Leakage Test

1.4.1 Connect facility plumbing to engine valve oxidizer inlet.

1.4.2 Verify engine valve is closed by venting off penumatic actuator open pressure. Valve should close by spring force.

1.4.3 Apply 150 ±10 psig GN_2 at oxidizer valve inlet.

1.4.4 Open facility valve downstream of throat plug and check for oxidizer valve internal leakage in H_2O container. Wait 5 minutes minimum; 5 scim is maximum leakage allowed. Record ______ ______________________________

1.4.5 Vent off engine valve inlet pressure to zero.

1.4.6 Disconnect facility hardware.

2.0 VERNIER ENGINE ASSEMBLY--PROPELLANT DECONTAMINATION

To be performed on Vernier Engine assembly when it is removed from Target Engine System or is tested as a unit on hot-fire test stand. Engine fuel and oxidizer purges are used for testing purposes only.

2.1 Engine Assembly (With Engine Valve Closed)

2.1.1 Oxidizer Side--Purge with GN_2 at 150 ±10 psig for 5 minutes minimum at engine valve purge port, exiting at TCA nozzle.

2.2.2 Fuel Side--Purge with GN_2 at 150 ±10 psig for 10 minutes minimum at engine valve purge port, exiting at TCA nozzle.

2.1.3 Oxidizer and Fuel Side--Install throat plug connected to water aspirator and vacuum dry at 25 to 30 inch Hg for 15 minutes minimum.

2.2 Engine Assembly (With Engine Valve Closed)

2.2.1 Fuel Side--Purge with GN_2 at 150 ±10 psig for 10 minutes minimum at inlet exiting through test facility bleed valve upstream of Hydromatics valve.

2.2.2 Oxidizer Side--Purge with GN_2 at 150 ±10 psig for 10 minutes minimum at inlet, exiting through facility bleedvalve upstream of Hydromatics valve.

2.3 Engine Assembly (With Throat Plug Installed)

2.3.1 Fuel Side--Flush with isopropyl alcohol (TT-1-735, Grade A) at 150 ±10 psig through inlet, exiting through throat plug. Maintain 50 ±10 psig back pressure at throat plug, using a throttle valve downstream of throat plug. Flush for 5 minutes minimum with engine valve open. Cycle engine valve close/open 4 to 8 times during the 5-minute flush (30 seconds close each time).

2.3.2 Oxidizer Side--Flush with Freon solvent (MIL-C-81302) at 150 ±10 psig through inlet, exiting through throat plug. Maintain 50 ±10 psig back pressure at throat plug, using a throttle valve downstream of throat plug. Flush for 5 minutes minimum with engine valve open. Cycle engine valve close/open 4 to 8 times during the 5-minute flush (30 seconds close each time).

2.3.3 Fuel and Oxidizer Side--Simultaneously purge the oxidizer and fuel sides with GN_2 at 150 ±10 psig through the inlets,exiting through the throat plug. Maintain a 50±10 psig back pressure at the throat plug, using a downstream throttle valve. Cycle the Hydromatics valve close/open 5 to 10 times during the purge. Purge for 10 minutes minimum.

2.3.4 Engine Assembly (With Engine Valve Open)--Vacuum dry engine assembly at 25 to 30 inches Hg for 1 hours minimum.

3.0 PNEUMATIC REGULATOR--PRESSURE SETTING

3.1 Regulator Setting-Check and Adjustment

3.1.1 Disconnect TEST GN_2 lines from pressurizing check valve to propellant tanks (oxidizer and fuel). Cap exposed ports.

3.1.2 Connect 0- to 3000-psig filtered GN_2 system to SP02 (Fig. A-2). Source should have pressure monitor and relief valve set for 3500 ±100 psig.

3.1.3 Connect 0- to 1000-psig pressure gage (1/4% accuracy) to SP03.

3.1.4 Adjust source pressure to 2500 ±50 psig.

3.1.5 Open bleed valve on TES regulator and set TES regulator-out pressure on gage at SP03 to the following:

TEM-1	=	270 ±2 psig
TEM-2	=	270 ±2 psig
TEM-3	=	520 ±4 psig

3.1.6 Torque lock nut on TES regulator adjust nut between 180 and 230 in.-lb. Safety wire lock nut.

3.1.7 Verify that TES regulator outlet pressure has not shifted more than 2 psi from set value in 3.1.5. Record final regulator set point: ________________psig.

3.1.8 Close GN_2 supply system shutoff valve.

3.1.9 Close TES regulator bleed valve when gage at SP03 reads zero.

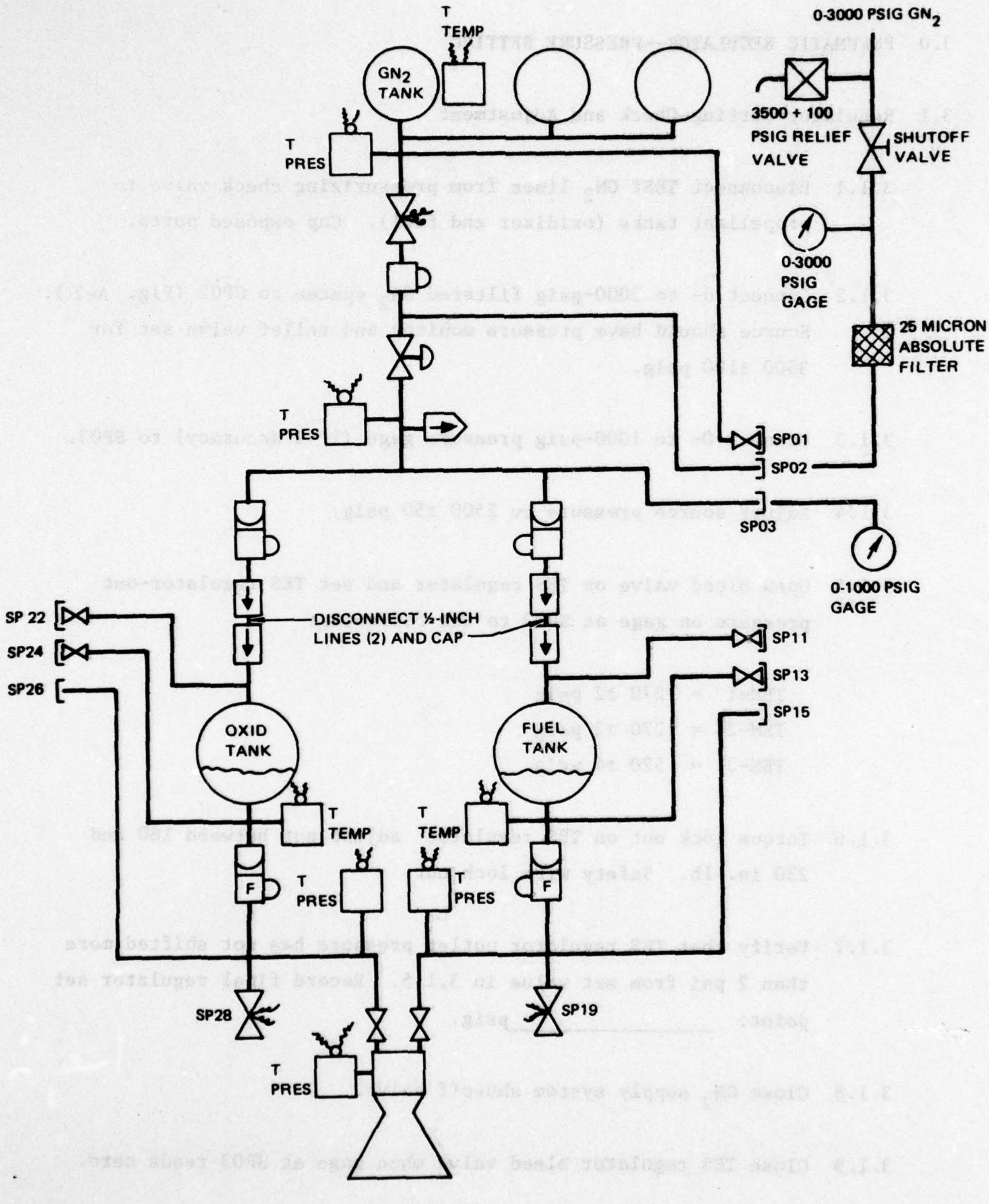


Figure A-2. Pneumatic Regulator - Pressure Setting

3.1.10 Remove pressure gage at SP03 and cap TES port at SP03.

3.1.11 Reconnect TES GN_2 pressurizing lines (2) between check valve and propellant tank. Torque to between 450 to 525 in.-lb.

4.0 SQUIB VALVE CHECKOUT (P/N TEP 1025)

The procedure will be accomplished prior to preflight installation and system leak check.

4.1 Check that P/N TEP 1025 (Fig. A-3) has been vibro-etched on housing of each part indicating that the particular assembly was proof-pressure tested to 4500 psig.

4.2 Visually observe that position indicators (two places) are retracted, indicating that the valves have not been fired inadvertently. Note condition on data sheet.

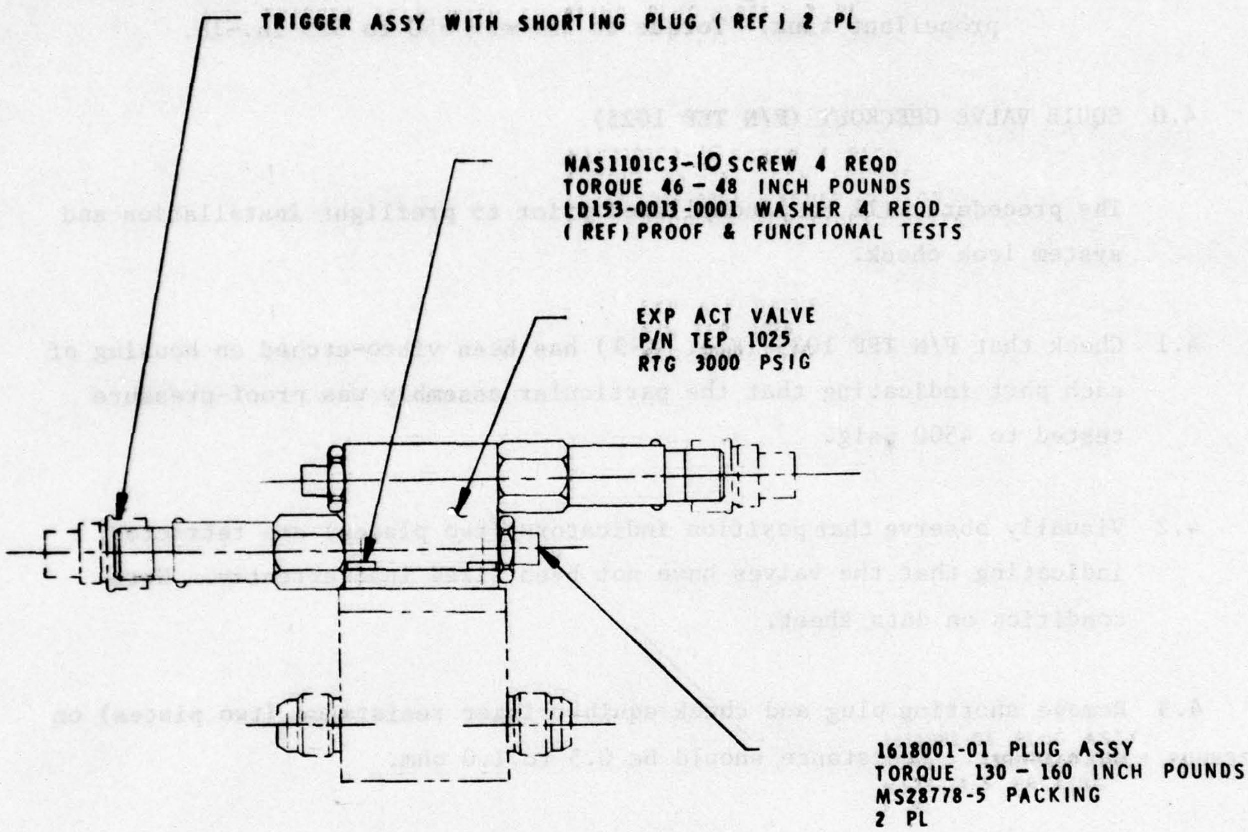
4.3 Remove shorting plug and check squib trigger resistance (two places) on data sheet. Resistance should be 0.5 to 1.0 ohm.

<u>CAUTION</u>: Continuity test device must limit current input to squib to maximum of 10 milliamps.

Immediately replace shorting plug when test is concluded.

4.4 Install squib valve assemblies on Target Engine System. Use new O-rings, RD 262-4012-0013 lubed with Krytox. Torque screws to between 19 and 24 in.-lb.

4.5 Record serial numbers of squib valve as to location on system. See data sheet.



	GN_2 Isolation	Fuel Dump	Oxidizer Dump
Valve S/N			
Plug Assembly Visual Check			
Trigger Resistance*			

*0.75 ±0.25 ohms, required; test device must limit current input to squib to a maximum of 10 millamps.

Figure A-3. Squib Valve Checkout

5.0 TRANSDUCER CHECK (PRESSURE AND TEMPERATURE)

Transducer output check shall be made prior to system leak and functional tests. Transducer output calibration check should be measured as an output from the integrated propulsion and ACS modules.

Pressure transducer output check shall be made by disconnecting sensing lines and applying GN_2 from a clean source with accurate pressure-measuring system. Temperature transducers may be removed from system for output check.

Transducer output shall be related to prior integrated system test data. Transducer output within ±5% of full scale is acceptable. A transducer output shift greater than ±5% will require system trouble-shooting for fault isolation and resolution.

6.0 SYSTEM LEAK AND FUNCTIONAL TESTS

This check will verify the following:

- Burst diaphragm (4) integrity
- Engine propellant valve actuation
- System integrity (leak test)

Checks will be performed at low pressure (50 psig) to remain below burst diaphragm design rupture pressure of between 110 and 160 psid.

Special equipment required includes the following:

- Rocket engine throat plug
- 28-vdc power supply to operate engine valve

- GN_2 supply filtered to 25 microns absolute, with shutoff valve, vent valve, and relief valve set at 60 ±2 psig
- Leak check compound (soap solution)

6.1 Burst Diaphragm Integrity

6.1.1 Connect test GN_2 system to SP11 (see Fig. A-4)

6.1.2 Adjust test GN_2 system regulator to 50 ±2 psig; open test shutoff valve

6.1.3 Open TES hand valve at SP11, pressurizing TES fuel tank to 50 psig

6.1.4 Leak check all external joints with soap solution from MMH gas-side burst diaphragm to MMH liquid burst diaphragm

6.1.5 MMH liquid burst diaphragm check

6.1.5.1 Attach a leak rate device to SP15 (U-tube in beaker of water)

6.1.5.2 Monitor for leakage across the MMH liquid-side burst diaphragm for 10 minutes minimum. No leakage is allowed.

6.1.5.3 Remove leak rate monitor from SP15

6.1.6 Close test GN_2 system shutoff valve and vent TES fuel tank pressure to zero

6.1.7 Remove test GN_2 system from SP11 and connect to SP22

6.1.8 Open test shutoff valve

6.1.9 Open TES hand valve at SP22, pressurizing TES oxidizer tank to 50 psig

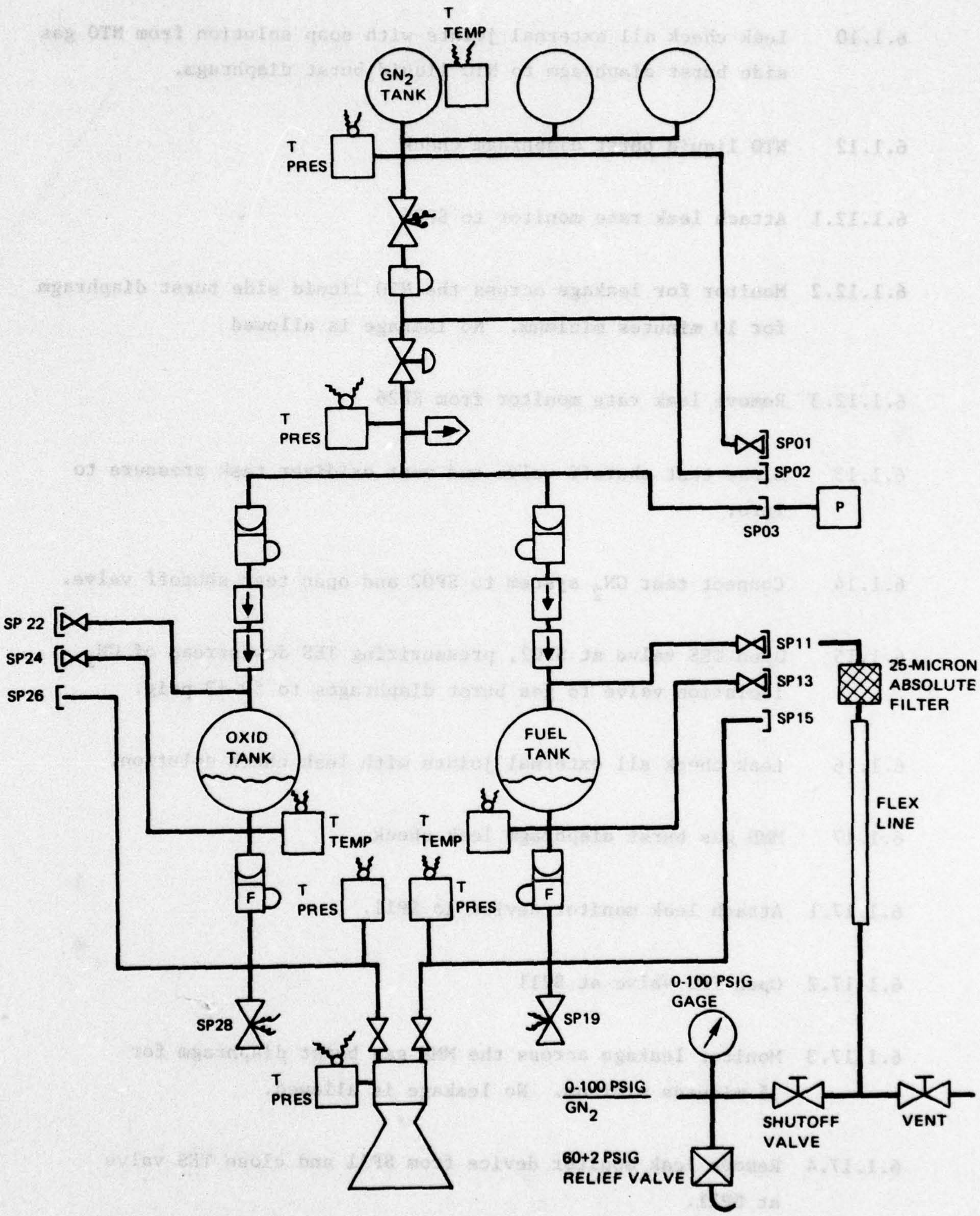


Figure A-4. System Leak and Functional Tests

6.1.10 Leak check all external joints with soap solution from NTO gas side burst diaphragm to NTO liquid burst diaphragm.

6.1.12 NTO liquid burst diaphragm check

6.1.12.1 Attach leak rate monitor to SP26

6.1.12.2 Monitor for leakage across the NTO liquid side burst diaphragm for 10 minutes minimum. No leakage is allowed

6.1.12.3 Remove leak rate monitor from SP26

6.1.13 Close test shutoff valve and vent oxidizer task pressure to zero.

6.1.14 Connect test GN_2 system to SP02 and open test shutoff valve.

6.1.15 Open TES valve at SP02, pressurizing TES downstream of GN_2 isolation valve to gas burst diaphragms to 50 ±3 psig.

6.1.16 Leak check all external joints with leak check solution.

6.1.17 MMH gas burst diaphragm leak check

6.1.17.1 Attach leak monitor device to SP11.

6.1.17.2 Open TES valve at SP11

6.1.17.3 Monitor leakage across the MMH gas burst diaphragm for 15 minutes minimum. No leakage is allowed.

6.1.17.4 Remove leak monitor device from SP11 and close TES valve at SP11.

6.1.18 NTO gas burst diaphragm leak check

6.1.18.1 Attach leak monitor device to SP22.

6.1.18.2 Open TES valve at SP22

6.1.18.3 Monitor leakage across the NTO gas burst diaphragm for 15 minutes minimum. No leakage is allowed.

6.1.18.4 Remove leak monitor device from SP22 and close TES valve at SP22

6.1.19 Close test GN_2 system shutoff valve.

6.1.20 Open TES valve at SP03, venting system to zero.

6.1.21 Connect test GN_2 system to TES at SP01.

6.1.22 Open test shutoff valve

6.1.23 Open TES valve at SP01, pressurizing the high-pressure. GN_2 system to 50 psig.

6.1.24 Leak check all external joints in the TES high-pressure GN_2 subsystem with leak check compound.

6.1.25 Close test GN_2 system shutoff valve and vent TES to zero.

6.1.26 Connect test GN_2 system to SP26 and SP15 (teed).

6.1.27 Install throat plug rocket engine and remove cap from throat plug vent.

6.1.28 Pressurize TES oxidizer and fuel systems downstream of liquid burst diaphragms to 50 ±3 psig.

6.1.29 Leak check TES NTO and MMH subsystems from liquid burst diaphragms to engine valve, using soap solution.

6.1.30 Open engine propellant valve with 28 ±2 vdc signal. Audible GN_2 flow will be heard at vent in throat plug verifying valve actuation.

6.1.31 Cap vent in throat plug and leak check affected rocket engine assembly joints with soap solution.

6.1.32 Close engine propellant valve.

6.1.33 Open vent in throat plug, venting combustion volume to zero pressure.

6.1.34 Attach leak rate monitor to vent port in throat plug.

6.1.35 Monitor propellant valve leakage for 5 minutes minimum. Total leakage, oxidizer and fuel, shall not exceed 2 sccm (RS-14 engine) or 10 scim (Atlas Vernier engine).

6.1.36 Close test GN_2 system shutoff valve and vent TES to zero.

6.1.37 Remove leak check monitor and engine throat plug.

6.1.38 Disconnect test GN_2 system from SP15 and SP26.

6.1.39 Cap ports at SP15 and SP26.

7.0 FUEL HANDLING PROCEDURES

The following procedures are included in this section.

- MMH Tanking, FTU - 7.1
- MMH Tanking, TES Hookup - 7.2
- MMH Tanking, TES - 7.3
- MMH Detanking and Decontamination, FTU - 7.4
- MMH Detanking, TES - 7.5
- MMH Decontamination, TES - 7.6

Tanking, detanking, and decontamination will be accomplished using a GFP propellant service unit: P/N SG201025-1 (Red) - Fuel Tanking Unit (FTU).

This unit has been modified as shown in Fig. A-6. The prescribed amount of propellants will be loaded using this unit and calibrated platform scales having a dial readout. Protective clothing will be worn during the tanking operation by those personnel directly exposed to the propellants. A source of running water shall be available during tanking, detanking, and decontamination operations. For operations, refer to Fig. A-5 and A-6.

7.1 <u>MMH Tanking, FTU</u>

CAUTION: FTU shall be uncontaminated with alcohol. See Section 7.4 for FTU cleaning operations.

7.1.1 Place the FTU on platform scales. Read and record initial weight, paragraph 7.1.6. Calculate target weight by adding 60 pounds to initial weight. Record target weight in 7.1.6.

7.1.2 Connect the FTU to an MMH source per MIL-P-25508 at FTP1.

7.1.3 Open "vent valve" on FTU.

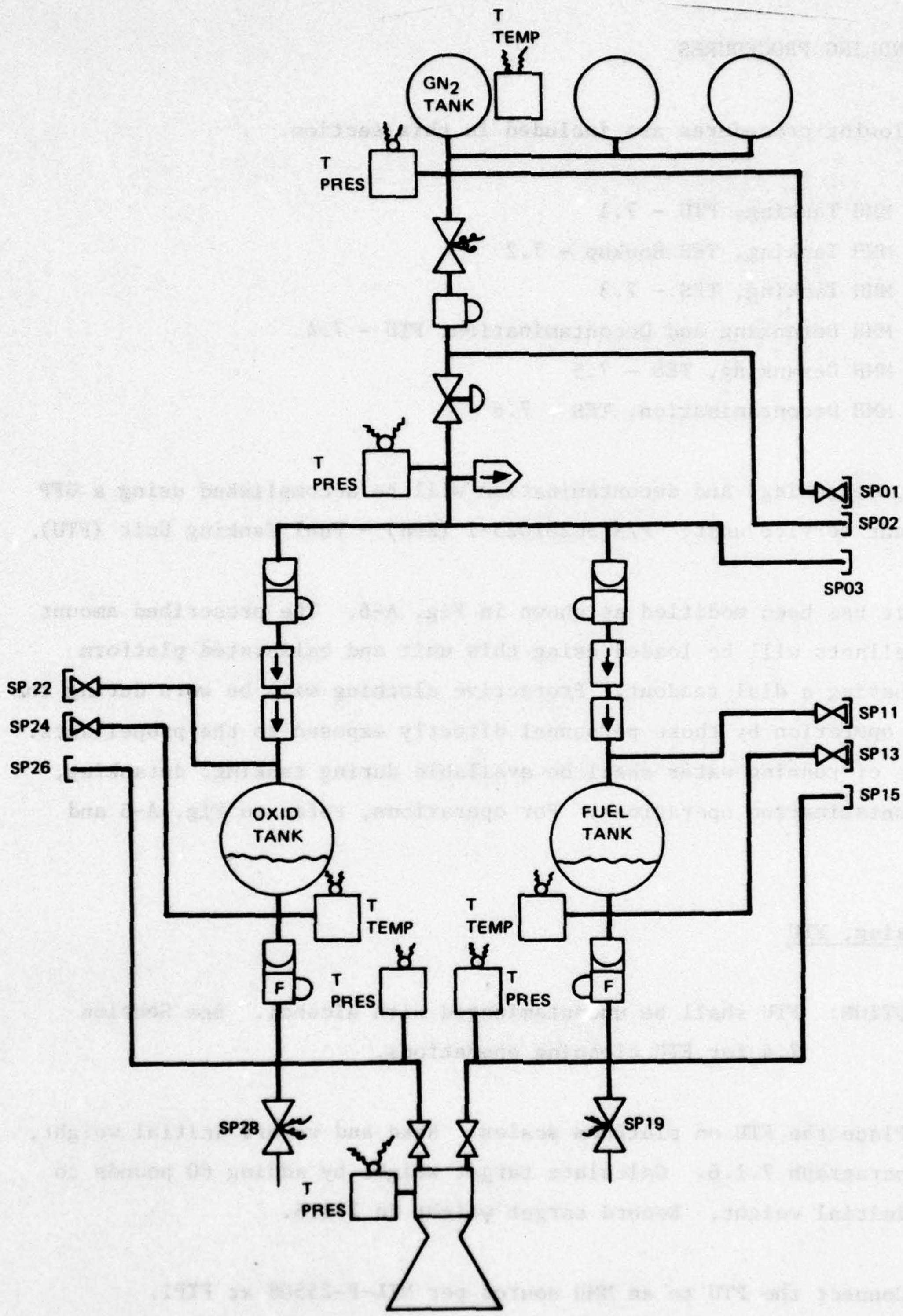


Figure A-5. Fuel Handling Procedures (Procedure 7.0)

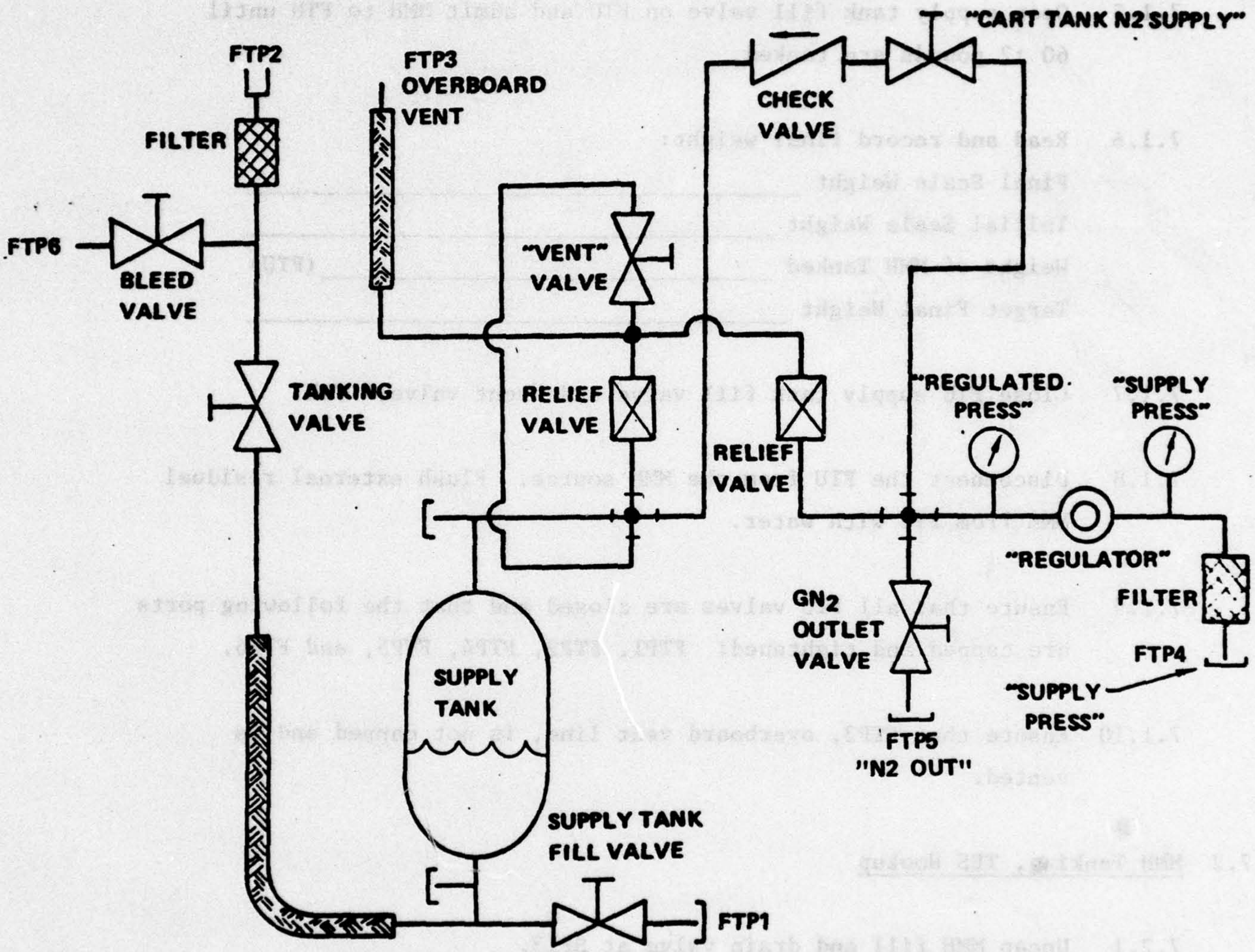


Figure A-6. Fuel Tanking Unit (FTU)

7.1.4 Close all other valves on FTU.

7.1.5 Open supply tank fill valve on FTU and admit MMH to FTU until 60 ±2 pounds are tanked.

7.1.6 Read and record final weight:

Final Scale Weight ______________________________

Initial Scale Weight ______________________________

Weight of MMH Tanked __________________________ (FTU)

Target Final Weight ______________________________

7.1.7 Close FTU supply tank fill valve and "vent valve," FTU.

7.1.8 Disconnect the FTU from the MMH source. Flush external residual MMH from FTU with water.

7.1.9 Ensure that all FTU valves are closed and that the following ports are capped and tightened: FTP1, FTP2, FTP4, FTP5, and FTP6.

7.1.10 Ensure that FTP3, overboard vent line, is not capped and is vented.

7.2 MMH Tanking, TES Hookup

7.2.1 Uncap MMH fill and drain valve at SP13.

7.2.2 Connect FTP2, FTU to SP13, TES MMH fill and drain valve.

NOTE: Inlet fitting on the TES MMH fill and drain valve is 3/16-inch AN.

7.2.3 Uncap TES MMH vent valve at SP11 and connect overboard vent line to this port.

NOTE: Inlet fitting on the TES MMH vent valves is 3/16-inch AN.

7.2.4 Attach an overboard dump line downstream of FTU bleed valve at FTP6.

7.2.5 Assure that all valves and the "regulator" on the FTU are closed.

7.2.6 Connect GN_2 supply (1000 ±500 psig) facility source to FTP4, FTU.

7.2.7 Open facility GN_2 supply valve, pressurizing FTU. Monitor pressure on FTU "supply pressure" gage.

7.2.8 Adjust FTU "regulator" to 60 ±30 psig as read on "regulated pressure" gage.

7.2.9 Ensure that TES MMH fill and drain valve at SP13 is closed.

7.2.10 Open FTU "cart tank N_2 supply" valve.

7.2.11 Partially open FTU tanking valve and partially open bleed valve. Close bleed valve when adequate fuel bleed has been noted at overboard dump line exit. Close FTU tanking valve.

CAUTION: Do not bleed MMH overboard for more than 4 seconds total.

7.3 MMH Tanking, TES

7.3.1 Read and record initial weight, paragraph 7.3.6. Calculate target weight by adding 56 pounds to initial weight. Record target weight in paragraph 7.3.6.

7.3.2 Open TES MMH vent valve, SP11.

7.3.3 Open TES fuel fill and drain valve, SP13.

7.3.4 Partially open FTU tanking valve and tank MMH into TEST MMH tank. Monitor scale dial for loss of weight indicating transfer of MMH. Adjust FTU "regulator" and/or tanking valve, as required, to attain the desired tanking flowrate.

7.3.5 When 56 ±1 pounds of MMH have been tanked, close FTU tanking valve.

7.3.6 Read and record final scale weight:

Initial Scale Weight ______________________

Final Scale Weight ______________________

Weight of MMH Tanked ______________________

Target Final Weight ______________________

7.3.7 Close TES MMH fill and drain valve, SP13.

7.3.8 Close TES MMH vent valve, SP11.

7.3.9 Remove vent line from SP11 and cap TES MMH vent valve.

7.3.10 Close FTU "cart tank N_2 supply valve" and reduce FTU regulator pressure to zero.

7.3.11 Open FTU "vent valve."

7.3.12 Open FTU "tank valve" for 30 seconds, then close.

7.3.13 Open FTU bleed valve, venting MMH overboard. Close bleed valve FTU when MMH flow ceases.

7.3.14 Disconnect overboard line from FTU bleed valve, taking precaution to drain line contents and/or flush any MMH spillage with water.

7.3.15 Disconnect FTU line at FTP2 from TES at SP13, taking precautions for flushing any MMH spillage from TES and tanking line upon line removal.

7.3.16 Cap TES MMH fill and drain valve.

7.4 MMH Detanking and Decontamination, FTU

7.4.1 Place FTU tanking line at FTP2 in MMH storage tank, suitable catch tank, or sump drainage system.

7.4.2 Adjust FTU regulator outlet pressure to 50 ±25 psig.

7.4.3 Open (crack) tanking valve and dump residual MMH from FTU.

7.4.4 When MMH flow ceases, allow GN_2 to purge system out for 5 minutes minimum.

7.4.5 Close "cart tank N_2 supply" valve, allowing FTU supply tank to vent to zero.

7.4.6 Connect FTU to source of isopropyl alcohol per TT-1-735, Grade A, at FTP1.

7.4.7 Crack B-nut cap at tee on top of FTU supply tank.

7.4.8 Open "vent valve" on FTU. Ensure that FTU tanking valve is closed.

7.4.9 Fill FTU with alcohol by opening FTU supply tank fill valve. Close supply tank fill valve when alcohol is noted at vented B-nut fitting on top of tank.

7.4.10 Close FTU "vent valve."

7.4.11 Tighten B-nut cap at tee on top of supply tank.

7.4.12 Disconnect alcohol supply line and cap FTP1.

7.4.13 Open FTU "cart tank N_2 supply" valve.

7.4.14 Place FTU tanking line at FTP2 in suitable catach tank or sump drainage system.

7.4.15 Open (crack) the FTU tanking valve and dump approximately one-half of the isopropyl alcohol overboard. Close FTU tanking valve.

7.4.16 Agitate the remaining alcohol in the FTU supply tank by manual sloshing for a minimum of 1 minute.

7.4.17 Open (crack) the FTU tanking valve and dump the remainder of the alcohol overboard, occoasionally opening the FTU bleed valve and flushing through bleed valve.

7.4.18 When the alcohol has been dumped, allow GN_2 to purge through the supply tank for a minimum of 5 minutes at 60 ±30 psig purge pressure.

7.4.19 Close facility GN_2 supply valve and allow FTU to vent to zero pressure. Close FTU regulator.

7.4.20 Disconnect facility GN_2 supply system from FTU at FTP4.

7.4.21 Close "cart tank N_2 supply" valve.

7.4.22 Connect facility aspirator to FTP2 and FTP1 (teed).

7.4.23 Open FTU bleed valve and tanking valve and aspirate supply tank for 30 minutes minimum at 22 inches Hg vacuum minimum.

7.4.24 Disconnect aspirator system from FTP2 and FTP1.

7.5.25 Close all valves on FTU.

7.4.26 Cap all fittings on FTU.

7.5 MMH Detanking, TES

This procedure should be used if the MMH in the TES fuel tank is of sufficient amount to be reclaimed. TES burst diaphragms are intact for this procedure.

CAUTION: Have a source of running water available to flush any MMH spillage from TES and FTU hardware.

7.5.1 Remove caps at TES SP11 and SP13.

7.5.2 Ensure that all valves on the FTU are closed.

7.5.3 Connect the FTU tanking line at FTP2 to the TES at SP13.

7.5.4 Connect FTU FTP5 to TES SP11 using a clean flex line.

7.5.5 Connect facility 1000 ±500 psig GN_2 supply system to FTU at FTP4.

7.5.6 Open facility GN_2 supply valve and adjust FTU regulator out pressure to 50 ±10 psig. Monitor "regulated pressure" gage.

7.5.7 Open TES MMH vent valve, SP11.

7.5.8 Open FTU "GN_2 outlet valve," pressurizing TES MMH tank.

7.5.9 Open "vent" valve on FTU. Ensure that vent line is uncapped at FTP3.

7.5.10 Ensure that the FTU supply tank fill valve is closed and capped at FTP1

7.5.11 Open the TES MMH fill and drain valve at SP13.

7.5.12 Open (crack) FTU tanking valve, admitting MMH to FTU supply tank. Adjust FTU "regulator" and/or tanking valve to attain desired flowrate.

7.5.13 Close FTU tanking valve when GN_2 is heard at FTU overboard vent, FTP3.

NOTE: MMH fumes will be noted at FTP3.

7.5.14 Close FTU GN_2 outlet valve when fuel in MMH tank has been transferred, and allow TES MMH tank pressure to vent to zero.

7.5.15 Reduce FTU regulator pressure to zero.

7.5.16 Close TES MMH vent valve at SP11 and MMH fill and drain valve at SP13.

7.5.17 Close FTU "vent" valve.

7.5.18 Disconnect flex line from FTU, FTP5, to TES, SP11. Cap TES valve.

7.5.19 Disconnect FTU MMH tanking line, FTP2, from TES, SP13. Cap TES valve.

7.5.20 Conduct MMH detanking and decontamination, FTU, per paragraphs 7.4.1 through 7.4.26.

7.6 MMH Decontamination, TES

This procedure applies to the TES where the fuel burst diaphragms have been burst and the squib dump valves have been fired.

7.6.1 Fill fuel tanking unit (FTU) with isopropyl alcohol as follows.

7.6.1.1 Connect FTU to isopropyl alcohol source per TT-1-735, Grade A, at FTP1.

7.6.1.2 Close FTU tanking valve.

7.6.1.3 Open FTU vent valve.

7.6.1.4 Loosen B-nut fitting on top of FTU supply tank.

7.6.1.5 Open FTU supply tank fill valve and admit alcohol to FTU supply tank.

7.6.1.6 Close FTU supply tank fill valve when alcohol overflows at cracked B-nut fitting at top of supply tank.

7.6.1.7 Tighten loosened B-nut fitting on top of FTU supply tank.

7.6.1.8 Disconnect FTU from alcohol source and cap fitting at FTP1.

7.6.2 TES vacuum dry.

7.6.2.1 Connect facility aspirator to TES at SP13 and SP15 and SP19 (teed together) and aspirate TES fuel side for 30 minutes minimum at 20- to 24-inch Hg vacuum.

7.6.2.2 Disconnect facility aspirator and close TES MMH fill and drain valve at SP13.

7.6.3 MMH decontamination hookup.

7.6.3.1 Connect FTU tanking line FTP2 to TES SP13. Open TES valve at SP13.

7.6.3.2 Connect dump line at FTU bleed valve.

7.6.3.3 Connect overboard dump lines at TES SP11 and SP19. Cap end of dump line at SP19.

7.6.3.4 Connect facility GN_2 supply (1000 ±500 psig) system at FTU FTP4. Open facility GN_2 supply valve.

7.6.4 Adjust FTU "regulator" to 60 ±30 psig. Monitor "regulated pressure" gage.

7.6.5 Open FTU "cart tank N_2 supply" valve.

7.6.6 Open TES MMH vent valve at SP11.

7.6.7 Open FTU tanking valve and admit alcohol to TES. Adjust FTU regulator and/or tanking valve to attain desired flowrate.

7.6.8 Close FTU tanking valve when alcohol in FTU supply tank has been exhausted.

NOTE: A gurgling noise may be heard in the FTU, or GN_2 will be noted coming from SP11, indicating the exhaustion of alcohol.

7.6.9 Refill FTU with alcohol.

7.6.9.1 Close facility GN_2 supply valve.

7.6.9.2 Close TES valve at SP13.

7.6.9.3 Open FTU bleed valve, allowing FTU and TES to vent to zero. Monitor pressure on FTU "regulated press" gage.

7.6.9.4 Disconnect FTU tanking line FTP2 at TES SP13.

7.6.9.5 Disconnect facility GN_2 supply line at FTP4.

7.6.9.6 Connect FTU to isopropyl alcohol source per TT-1-735, Grade A, at FTP1.

7.6.9.7 Close FTU tanking valve.

7.6.9.8 Open FTU vent valve.

7.6.9.9 Loosen B-nut fitting on top of FTU supply tank.

7.6.9.10 Open FTU supply tank fill valve and admit alcohol to FTU supply tank.

7.6.9.11 Close FTU supply tank fill valve when alcohol overflows at cracked B-nut fitting at top of supply tank.

7.6.9.11 Tighten loosened B-nut fitting on top of FTU supply tank.

7.6.9.12 Disconnect FTU from alcohol source and cap fitting at FTP1.

7.6.10 MMH Decontamination - continued.

7.6.10.1 Connect FTU tanking line FTP2 to TES SP13.

7.6.10.2 Open TES valve at SP13.

7.6.10.3 Connect facility GN_2 supply (1000 ±500 psig) system at FTU FTP4. Open facility GN_2 supply valve.

7.6.10.4 Adjust FTU "regulator" to 60 ±30 psig. Monitor "regulated pressure" gage.

7.6.10.5 Open FTU "cart tank N_2 supply" valve.

7.6.10.6 Open TES MMH vent valve at SP11.

7.6.10.7 Open FTU tanking valve and admit alcohol to TES. Adjust FTU regulator and/or tanking valve to attain desired flowrate.

7.6.10.8 Continue filling fuel tank with alcohol. Allow alcohol to flow out dump line at SP11 for 15 seconds minimum. Close FTU tanking valve.

7.6.10.9 Remove dump line from TES SP11 and connect a clean flex line from FTU FTP5 to SP11.

7.6.10.10 Remove cap from end of dump line at SP19.

7.6.10.11 Open TES MMH vent valve at SP11.

7.6.10.12 Open FTU GN_2 outlet valve, pressurizing TES MMH tank.

7.6.10.13 Allow alcohol to flow from TES SP19 fro 15 seconds minimum.

7.6.10.14 Close FTU GN_2 outlet valve.

7.6.10.15 Cap end of dump line at SP19.

7.6.10.16 Open FTU GN_2 outlet valve, pressurizing TES MMH tank.

7.6.10.17 Open TES MMH fill and drain valve at SP15 (if accessible) and allow alcohol to dump overboard for 15 to 30 seconds. Close MMH fill and drain valve.

7.6.10.18 Open engine valve and dump remainder of alcohol in the MMH tank through the REA.

7.6.10.19 After alcohol has been exhausted from TES fuel system, allow system to be purged with GN_2 for 10 minutes minimum. Adjust purge pressure as required. Close FTU GN_2 outlet valve.

7.6.10.20 Close FTU regulator.

7.6.10.21 Open FTU vent valve.

7.6.10.22 Disconnect flex line from FTU FTP5 to TES SP11 and FTU tanking line from TES SP13.

7.6.11 TES vacuum dry.

7.6.11.1 Connect facility aspirator to TES SP11, SP13, SP15 (if accessible), and SP19 (teed together) and aspirate TES MMH system for 1 hour minimum at 22-inch Hg minimum.

7.6.11.2 At end of aspiration operation, remove facility plumbing and cap SP15 and SP19. Close TES valves at SP11 and SP13 and cap ports.

7.6.12 FTU alcohol dump.

7.6.12.1 Place FTU tanking line in suitable catch tank or sump drainage system. Remove cap at FTP2.

7.6.12.2 Adjust FTU regulator to 60 ±30 psig.

7.6.12.3 Open FTU "cart tank N_2 supply" valve.

7.6.12.4 Open FTU tanking valve and dump remainder of alcohol in supply tank overboard.

7.6.12.5 When alcohol has been dumped, allow GN_2 to purge through the FTU supply tank for 5 minutes minimum at 60 ±30 psig.

7.6.12.6 Close facility GN_2 supply pressure valve allowing FTU pressure to vent to zero. Close FTU regulator.

7.6.12.7 Disconnect GN_2 supply system for FTU.

7.6.12.8 Close "cart tank N_2 supply" valve.

7.6.12.9 Connect facility aspirator to FTP6 and FTP1 (teed).

7.6.12.10 Open FTU bleed valve tanking valve and supply tank fill valve, and aspirate supply tank for 30 minutes minimum at 22-inch Hg vacuum minimum.

7.6.12.11 Disconnect facility aspirator.

7.6.12.12 Close all FTU valves and cap all fittings on FTU.

8.0 OXIDIZER HANDLING PROCEDURES

The following procedures are included in this section:

- NTO Tanking, OTU - 8.1
- NTO Tanking TES Hookup - 8.2
- NTO Tanking, TES - 8.3

- NTO Detanking and Decontamination, OTU - 8.4
- NTO Detanking, TES - 8.5
- NTO Decontamination, TES - 8.6

Oxidizer, tanking, detanking, and decontamination will be accomplished using a GFP propellant servicing unit: P/N SQ201025-2 (Green) - Oxidizer Tanking Unit (OTU).

This unit has been modified as shown in Fig. A-8. The prescribed amount of propellant will be loaded using this unit and calibrated platform scales having a dial readout. Protective clothing will be worn during the tanking operation by those personnel directly exposed to the propellants. A source of running water shall be available during tanking, detanking, and decontramination operations. For operation, refer to Fig. A-7 and A-8.

8.1 <u>NTO Tanking, OTU</u>

CAUTION: OTU shall be uncontaminated with Freon solvent. See Section 8.4 for OTU cleaning operations.

8.1.1 Place the OTU on platform scales. Read and record initial weight, paragraph 8.1.6. Calculate target weight by adding 100 pounds to initial weight. Record target weight in 8.1.6.

8.1.2 Close all valves on OTU.

8.1.3 Connect the OTU to an NTO source per MIL-P-27404 at OTP1.

8.1.4 Open "vent valve" on OTU.

8.1.5 Open supply tank fill valve on OTU and admit NTO to OTU until 100 ±5 pounds are tanked.

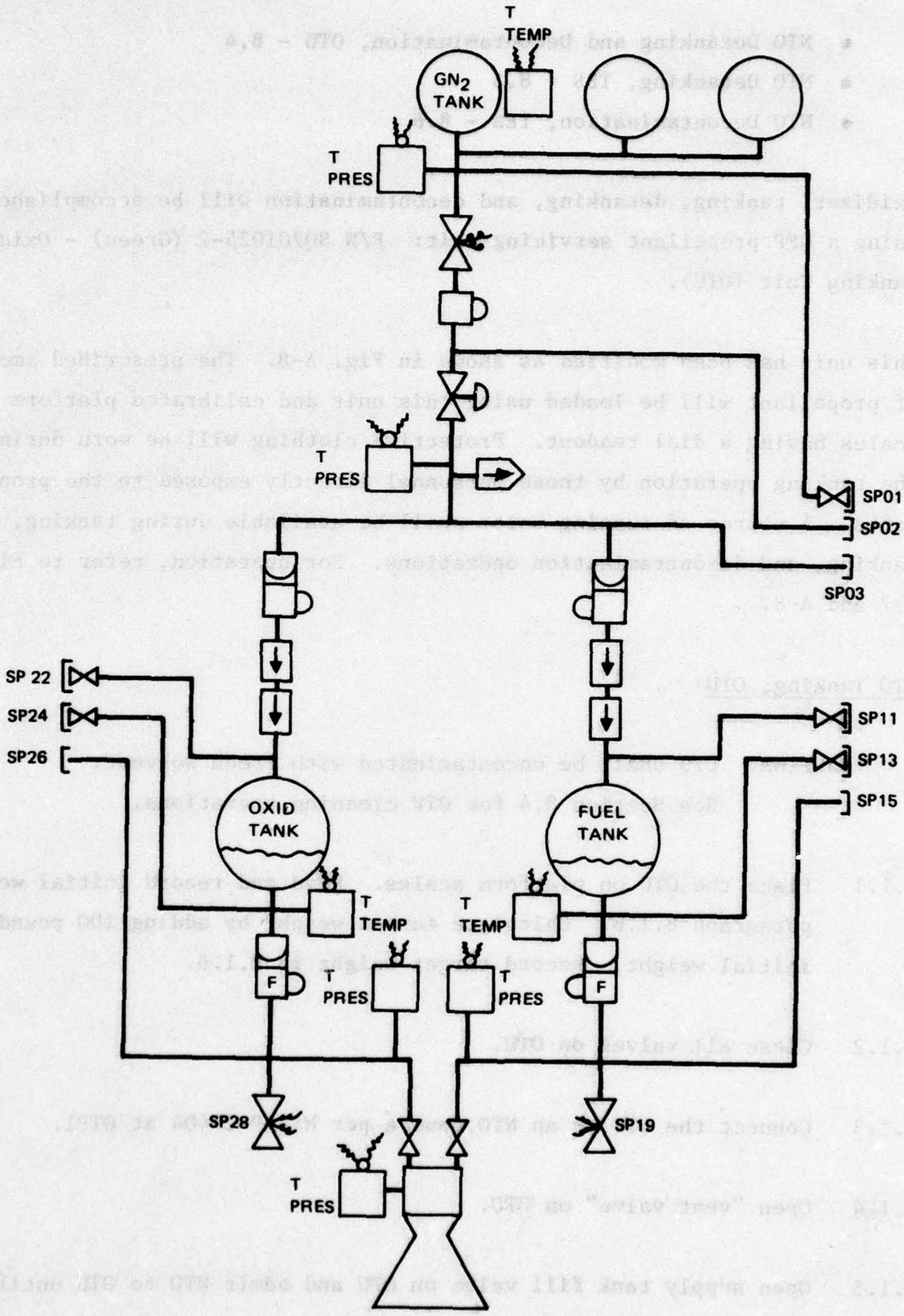


Figure A-7. Oxidizer Handling Procedures (Procedure 8.0)

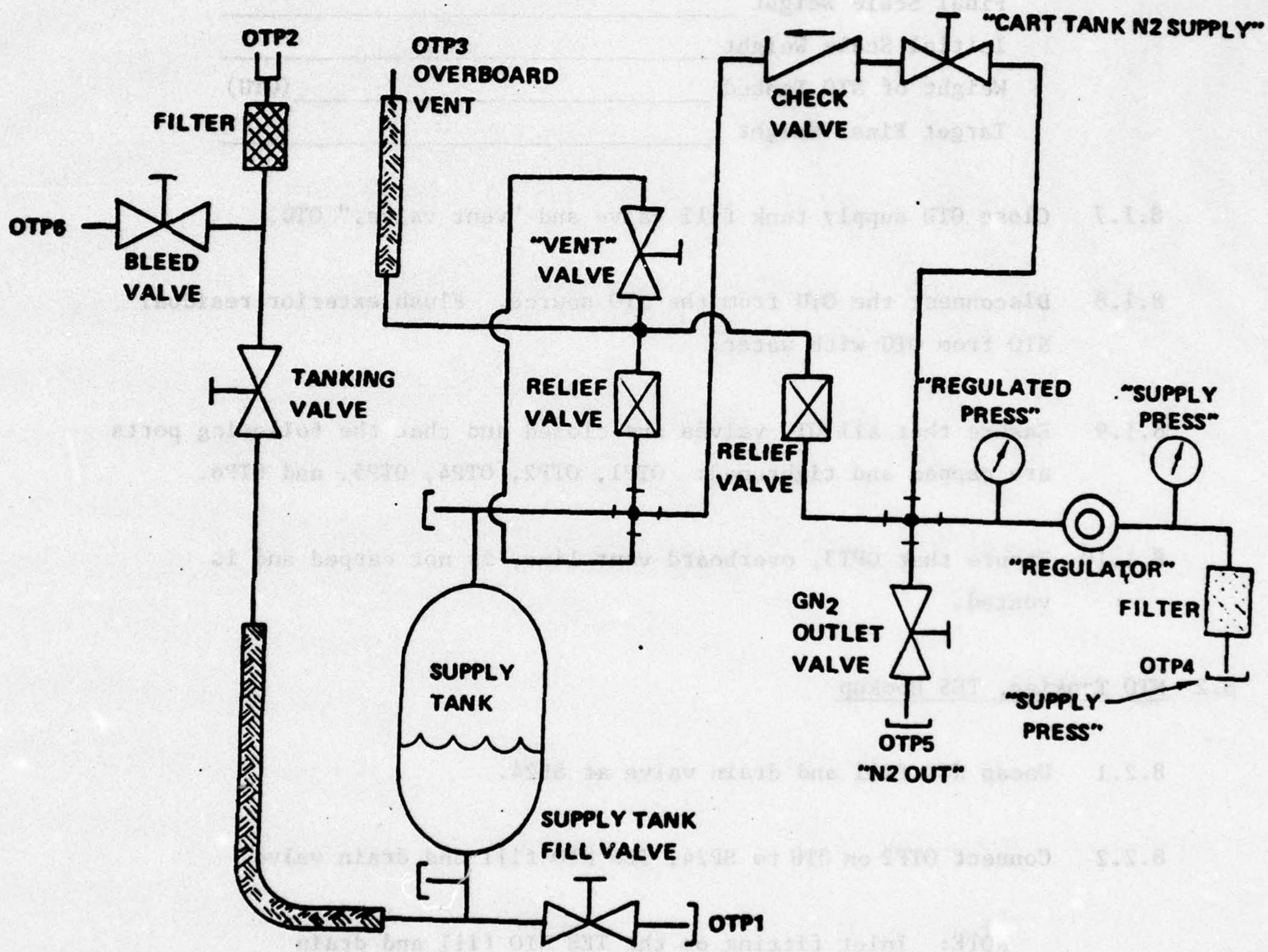


Figure A-8. *Oxidizer Tanking Unit (OTU)*

8.1.6 Read and record final weight:

Final Scale Weight ____________________

Initial Scale Weight ____________________

Weight of NTO Tanked ____________________ (OTU)

Target Final Weight ____________________

8.1.7 Close OTU supply tank fill valve and "vent valve," OTU.

8.1.8 Disconnect the OTU from the NTO source. Flush exterior residual NTO from OTU with water.

8.1.9 Ensure that all OTU valves are closed and that the following ports are capped and tightened: OTP1, OTP2, OTP4, OTP5, and OTP6.

8.1.10 Ensure that OPT3, overboard vent line, is not capped and is vented.

8.2 <u>NTO Tanking, TES Hookup</u>

8.2.1 Uncap NTO fill and drain valve at SP24.

8.2.2 Connect OTP2 on OTU to SP24, TES NTO fill and drain valve.

NOTE: Inlet fitting on the TES NTO fill and drain valve is 1/4-inch AN.

8.2.3 Uncap TES vent valve at SP22 and connect overboard vent line to this port.

NOTE: Inlet fitting on the TES NTO vent valves 1/4-inch AN.

8.2.4 Attach an overboard dump line downstream of OTU bleed valve at OTP6.

8.2.5 Assure that all valves and the "regulator" on the OTU are closed.

8.2.6 Connect GN_2 supply (1000 ±500 psig) facility source to OTP4, OTU.

8.2.7 Open facility GN_2 supply valve, pressurizing OTU. Monitor pressure on OTU "supply pressure" gage.

8.2.8 Adjust OTU "regulator" to 60 ±30 psig as read on "regulated pressure" gage.

8.2.9 Ensure that TES NTO fill and drain valve at SP24 is closed.

8.2.10 Open OTU "cart tank N_2 supply" valve.

8.2.11 Partially open OTU tanking valve and partially open bleed valve. Close bleed valve when adequate oxidizer bleed has been noted at overboard dump line exit. Close OTU tanking valve.

CAUTION: Do not bleed NTO overboard for more than 4 seconds total.

8.3 NTO Tanking, TES

8.3.1 Read and record initial weight, paragraph 8.3.6. Calculate target weight by adding 90 pounds to initial weight. Record target weight in paragraph 8.3.6.

8.3.2 Open TES NTO vent valve, SP22.

8.3.3 Open TES oxidizer fill and drain valve, SP24.

8.3.4 Partially open OTU tanking valve and tank NTO into TES NTO tank. Monitor scale dial for loss of weight, indicating transfer of NTO. Adjust OTU "regulator" and/or tanking valve, as required, to attain the desired tanking flowrate.

8.3.5 When 90 ±1 pounds of NTO have been tanked, close OTU tanking valve.

8.3.6 Read and record final scale weight:

Initial Scale Weight ____________________

Final Scale Weight ____________________

Weight of NTO Tanked ____________________ (TES)

Target Final Weight ____________________

8.3.7 Close TES NTO fill and drain valve, SP24.

8.3.8 Close TES NTO vent valve, SP22.

8.3.9 Remove vent line from SP22 and cap TES NTO vent valve.

8.3.10 Close OTU "cart tank N_2 supply" valve and reduce FTU regulator pressure to zero.

8.3.11 Open OTU vent valve

8.3.12 Open OTU tank valve for 30 seconds then close.

8.3.13 Open OTU bleed valve, venting NTO overboard. Close bleed valve when NTO flow ceases.

8.3.14 Disconnect overboard line from OTU bleed valve, taking precaution to drain line contents and/or flush any NTO spillage with water.

8.3.15 Disconnect OTU line at OTP2 from TES at SP24, taking precautions to flush any NTO spillage from TES and tanking line upon line removal.

8.3.15 Cap TES NTO fill and drain valve, SP24.

8.4 NTO Detanking and Decontamination, OTU

8.4.1 Place OTU tanking line at OTP2 in NTO storage tank, suitable catch tank, or sump drainage system.

8.4.2 Adjust OTU regulator outlet pressure to 50 ±25 psig.

8.4.3 Open (crack) tanking valve and dump residual NTO from OTU.

8.4.4 When NTO flow ceases, allow GN_2 to purge system out for 5 minutes minimum.

8.4.5 Close "cart tank N_2 supply" valve, allowing OTU supply tank to vent to zero.

8.4.6 Connect OTU to source of Freon solvent per MIL-C-81302.

8.4.7 Crack B-nut cap at tee on top of OTU supply tank.

8.4.8 Open "vent" valve on OTU.

NOTE: Ensure that OTU tanking valve is closed.

8.4.9 Fill OTU with Freon by opening OTU supply tank fill valve. Close supply tank fill valve when Freon is noted at vented B-nut fitting on top of tank.

8.4.10 Close OTU "vent" valve.

8.4.11 Tighten B-nut cap at tee on top of OTU supply tank.

8.4.12 Disconnect Freon supply line and cap OTP1.

8.4.13 Open OTU "cart tank N_2 supply" valve.

8.4.14 Place OTU tanking line at OTP2 in suitable catch tank or sump drainage system.

8.4.15 Open (crack) the OTU tanking valve and dump approximately one-half the Freon overboard. Close OTU tanking valve.

8.4.16 Agitate the remaining Freon in the OTU supply tank by manual sloshing for a minimum of 1 minute.

8.4.17 Open (crack) the OTU tanking valve and dump the remainder of the Freon overobard, occasionally opening the OTU bleed valve and flushing through bleed valve.

8.4.18 When the Freon has been dumped, allow GN_2 to purge through the supply tank for a minimum of 5 minutes at 60 ±30 psig purge pressure.

8.4.19 Close facility GN_2 supply valve and allow OTU to vent to zero pressure. Close OTU regulator.

8.4.20 Disconnect facility GN_2 supply system from OTU at OTP4.

8.4.21 Close "cart tank N_2 supply" valve.

8.4.22 Connect facility aspirator to OTP2 and OTP1.

8.4.23 Open OTU bleed valve and tanking valve and aspirate supply tank for 30 minutes minimum at 22-inch Hg vacuum minimum.

8.4.24 Disconnect aspirator system from OTP2 and OTP1.

8.4.25 Close all valves on OTU.

8.4.26 Cap all fittings on OTU.

8.5 NTO Detanking, TES

This procedure should be used if the NTO in the TES oxidizer tank is of sufficient amount to be reclaimed. TES burst diaphragms are intact for this procedure.

CAUTION: Have source of running water available to flush NTO spillage from TES and OTU hardware.

8.5.1 Remove caps at TES SP22 and SP24.

8.5.2 Ensure that all valves on the OTU are closed.

8.5.3 Connect the OTU tanking line at OTP2 to the TES at SP24.

8.5.4 Connect OTU OTP5 to TES SP22 using a clean flex line.

8.5.5 Connect facility 1000 ±500 spig GN_2 supply system to OTU at OTP4.

8.5.6 Open facility GN_2 supply valve and adjust OTU regulator out pressure to 50 ±10 psig. Monitor "regulated pressure" gage.

8.5.7 Open TES NTO vent valve, SP22.

8.5.8 Open OTU "GN_2 outlet valve, pressurizing TES NTO tank.

8.5.9 Open "vent" valve on OTU. Ensure that vent line is uncapped at OTP3.

8.5.10 Ensure that OTU supply tank fill valve is closed and capped at OTP1.

8.5.11 Open TES NTO fill and drain valve at SP24.

8.5.12 Open (crack) OTU tanking valve, admitting NTO to OTU supply tank. Adjust OTU "regulator" and/or tanking valve to attain desired flowrate.

8.5.13 Close OTU tanking valve when GN_2 is heard at OTU overboard vent, OTP3.

CAUTION: NTO fumes will be noted at OTP3.

8.5.14 Close OTU GN_2 outlet valve when oxidizer in NTO tank has been transferred, and allow TES NTO tank pressure to vent to zero.

8.5.15 Reduce OTU regulator pressure to zero.

8.5.16 Close TES NTO vent valve at SP22, and NTO fill and drain valve at SP24.

8.5.17 Close OTU "vent" valve.

8.5.18 Disconnect flex line from OTU OTP5 to TES, SP22. Cap TES valve.

8.5.19 Disconnect OTU NTO tanking line OPT2 from TES SP24. Cap TES valve.

8.5.20 Conduct NTO detanking and decontamination, OTU, paragraphs 8.4.1 through 8.4.26.

8.6 NTO Decontamination, TES

This procedure applies to the TES where the oxidizer burst diaphragms have been burst and squib dump valves have been fired.

8.6.1 Fill oxidizer tanking unit (OTU) with Freon solvent as follows.

8.6.1.1 Connect OTU to Freon solvent source per MIL-C-81302 at OTP1.

8.6.1.2 Close OTU tanking valve.

8.6.1.3 Open OTU vent valve.

8.6.1.4 Loosen B-nut fitting on top of OTU supply tank.

8.6.1.5 Open OTU supply tank fill valve and admit Freon to OTU supply tank.

8.6.1.6 Close OTU supply tank fill valve when Freon overflows at cracked B-nut fitting at top of supply tank.

8.6.1.7 Tighten loosened B-nut fitting on top of OTU supply tank.

8.6.1.8 Disconnect OTU from Freon source and cap fitting at OTP1.

8.6.2 TES vacuum dry

8.6.2.1 Connect facility aspirator to TES at SP24 and SP26 and SP28 (teed together), and aspirate TES oxidizer side for 30 minutes minimum at 22-inch Hg minimum.

8.6.2.2 Disconnect facility aspirator and close TES NTO fill and drain valve at SP24.

8.6.3 NTO decontamination hookup.

8.6.3.1 Connect OTU tanking line OTP2 to TES SP24. Open TES valve at SP24.

8.6.3.2 Connect dump line at OTU bleed valve.

8.6.3.3 Connect overboard dump lines at TES SP22 and SP28. Cap end of dump line at SP28.

8.6.3.4 Connect facility GN_2 supply (1000 ±500 psig) system at OTU OTP4. Open facility GN_2 supply valve.

8.6.4 Adjust OTU "regulator" to 60 ±30 psig. Monitor "regulator" to 60 ±30 psig. Monitor on "regulated pressure" gage.

8.6.5 Open OTU "cart tank N_2 supply" valve.

8.6.6 Open TES NTO vent valve at SP22.

8.6.7 Open OTU tanking valve and admit Freon to TES. Adjust OTU regulator and/or tanking valve to attain desired flowrate.

8.6.8 Close OTU tanking valve when Freon in OTU supply tank has been exhausted.

NOTE: A gurgling noise may be heard in the OTU or GN_2 will be noted coming from SP22, indicating the exhaustion of Freon.

8.6.9 Refill OTU with Freon solvent.

8.6.9.1 Close facility GN_2 supply valve.

8.6.9.2 Close TES valve at SP24.

8.6.9.3 Open OTU bleed valve, allowing OTU and TES to vent to zero. Monitor pressure on OTU "regulated pressure" gage.

8.6.9.4 Disconnect OTU tanking line OTP2 at TES SP24.

8.6.9.5 Disconnect facility GN_2 supply line at OTP4.

8.6.9.6 Connect OTU to Freon source per MIL-C-81302 at OTP1.

8.6.9.7 Close OTU tanking valve.

8.6.9.8 Open OTU vent valve.

8.6.9.9 Loosen B-nut fitting on top of OTU supply tank.

8.6.9.10 Open OTU supply tank fill valve and admit Freon to OTU supply tank.

8.6.9.11 Close OTU supply tank fill valve when Freon overflows at cracked B-nut fitting at top of supply tank.

8.6.9.12 Tighten loosened B-nut fitting on top of OTU supply tank.

8.6.9.13 Disconnect OTU from Freon source and cap fitting at OTP1.

8.6.10 NTO decontamination - continued

8.6.10.1 Connect OTU tanking line OTP2 to TES SP24.

8.6.10.2 Open TES valve at SP24.

8.6.10.3 Connect facility 1000 ±500 psig GN_2 system at OTU FTP4. Open facility GN_2 supply valve.

8.6.10.4 Adjust OTU "regulator" to 60 ±30 psig. Monitor "regulated pressure" gage.

8.6.10.5 Open OTU "cart tank N_2 supply" valve.

8.6.10.6 Open TES NTO vent valve at SP22.

8.6.10.7 Open OTU tanking valve and admit Freon to TES. Adjust OTU regulator and/or tanking valve to attain desired flowrate.

8.6.10.8 Continue filling oxidizer tank with Freon. Allow Freon to flow out dump line at SP22 for 15 seconds minimum. Close OTU tanking valve.

8.6.10.9 Remove dump line from TES SP22 and connect a clean flex line from OTU OTP5 to SP22.

8.6.10.10 Remove cap from end of dump line at SP28.

8.6.10.11 Open TES NTO vent valve at SP22.

8.6.10.12 Open OTU GN_2 outlet valve, pressurizing TES NTO tank.

8.6.10.13 Allow Freon to flow from TES SP28 for 15 seconds minimum.

8.6.10.14 Close OTU GN_2 outlet valve.

8.6.10.15 Cap end of dump line at SP28.

8.6.10.16 Open OTU GN_2 outlet valve, pressurizing TES NTO tank.

8.6.10.17 Open TES NTO fill and drain valve at SP26 (if accessible), and allow Freon to dump overboard for 15 to 30 seconds. Close NTO fill and drain valve.

8.6.10.18 Open engine valve and dump remainder of Freon in the NTO tank through the REA.

8.6.10.19 After Freon has been exhausted from TES oxidizer system, allow system to be purged with GN_2 for 10 minutes minimum. Adjust purge pressure as required. Close FTU GN_2 outlet valve.

8.6.10.20 Close OTU regulator.

8.6.10.21 Open OTU vent valve.

8.6.10.22 Disconnect flex line from OTU OTP5 to TES SP22 and OTU tanking line from TES SP24.

8.6.11 TES vacuum dry.

8.6.11.1 Connect facility aspirator to TES SP22, SP24 (if accessible), SP26, and SP28 (teed together) and aspirate TES NTO system for 1 hour minimum at 22-inch Hg minimum.

8.6.11.2 At end of aspiration operation, remove facility plumbing and cap SP26 and SP28. Close TES valves at SP22 and SP24 and cap ports.

8.6.12 OTU Freon dump

8.6.12.1 Place OTU tanking line in suitable catch tank or sump drainage system. Remove cap at OTP2.

8.6.12.2 Adjust OTU regulator to 60 ±30 psig.

8.6.12.3 Open OTU "cart tank N_2 supply valve."

8.6.12.4 Open OTU tanking valve and dump remainder of Freon in supply tank overboard.

8.6.12.5 When Freon has been dumped, allow GN_2 to purge through the OTU supply tank for 5 minutes minimum at 60 ±30 psig.

8.6.12.6 Close facility GN_2 supply pressure valve, allowing OTU pressure to vent to zero. Close OTU regulator.

8.6.12.7 Disconnect GN_2 supply system from OTU.

8.6.12.8 Close "cart tank N_2 supply" valve.

8.6.12.9 Connect facility aspirator to OTP6 and OTP1 (teed).

8.6.12.10 Open OTU bleed valve, tanking valve, and supply tank fill valve, and aspirate supply tank for 30 minutes minimum at 20-inch Hg vacuum minimum.

8.6.12.11 Disconnect facility aspirator.

8.6.12.12 Close all OTU valves and cap all fittings on OTU.

9.0 <u>GN_2 Charge Procedure</u>

9.1 Attach GN_2 fill line to TES GN_2 fill valve SP01 (Fig. A-9). This line should incorporate a filter (25 micron absolute), relief valve (set at 3650 ±25 psig), pressure gage (0 to 4000 psig), and facility charge valve (Fig. A-9). GN_2 source shall meet requirements of MIL-P-27401.

9.2 Activate thermocouple readout for TES GN_2 gas temperature.

9.3 Initially charge GN_2 tank to 3350 ±20 psig. Close facility charge valve.

9.4 Wait 15 minutes and read GN_2 tank gas temperature and pressure.

9.5 Plot point on curve (Fig. A-10) and adjust pressure accordingly. Vent off if above band and increase if below line.

9.6 Repeat steps 9.2 through 9.5 until proper amount of GN_2 is charged.

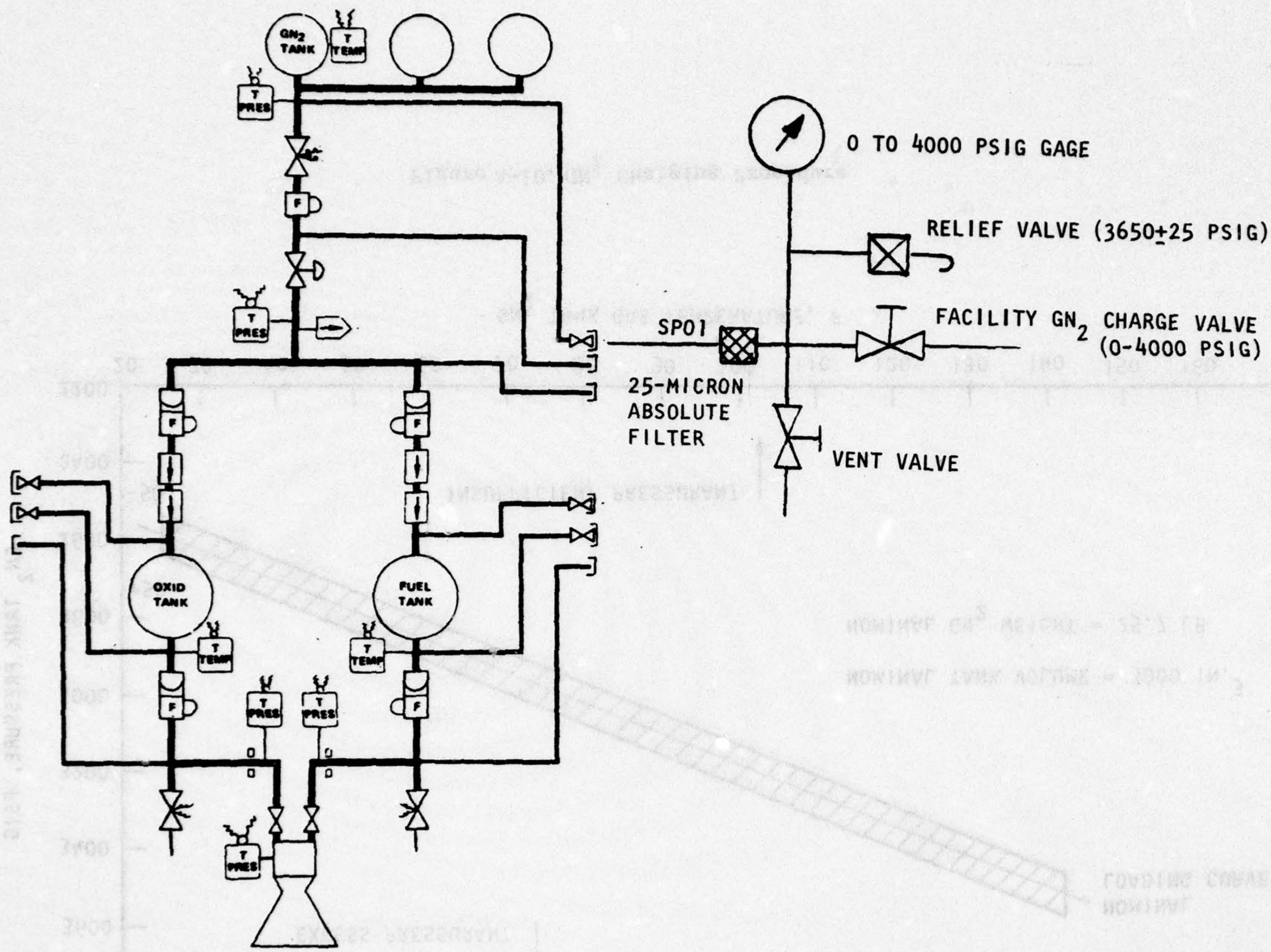


Figure A-9. GN_2 Charging Procedure (Procedure 9.0)

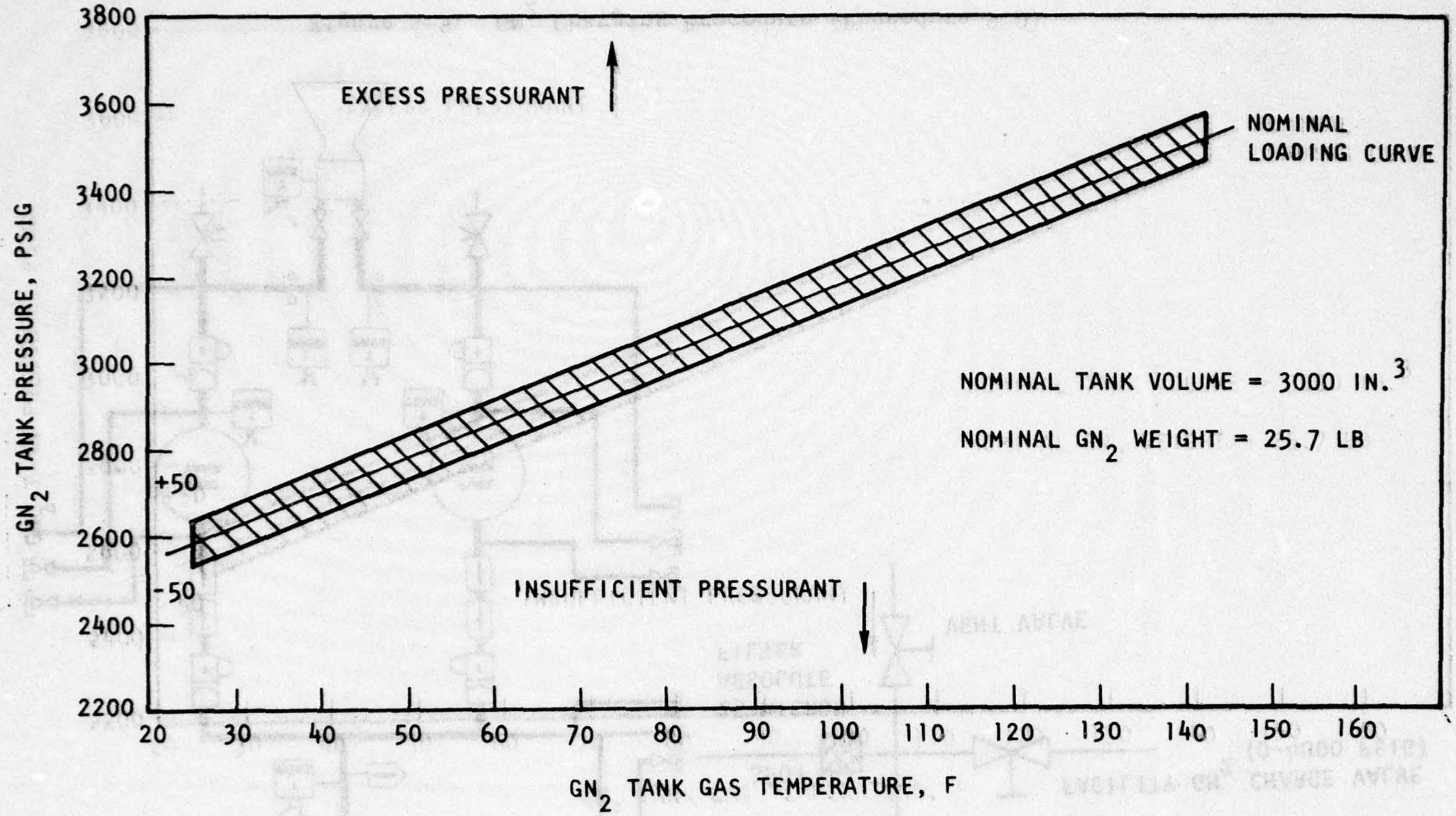


Figure A-10. GN_2 Charging Procedure

9.7 Close TES GN_2 charge valve at SP01, close facility charge valve, and open facility vent valve.

9.8 Disconnect facility charge line at SP01. Cap TES TN_2 charge valve.

9.9 Leak test TES TN_2 charge valve.

10.0 GN_2 DUMP PROCEDURE

This procedure is applicable when GN_2 must be vented prior to firing of the TES GN_2 squib valve.

10.1 Check that TES GN_2 fill valve is closed.

10.2 Remove cap from TES GN_2 fill valve.

10.3 Attach vent line to TES GN_2 fill valve.

10.4 Open (crack) TES GN_2 fill valve venting GN_2 tanks (3) to zero pressure.

10.5 When GN_2 tank pressure has decayed to zero, close TES GN_2 fill valve.

10.6 Remove dump line and cap SP01.

APPENDIX B

FIELD OPERATIONS AT LAUNCH SITE

This appendix outlines field operations concerned with launch site activities.

Section	Title
I	Target Engine System Prelaunch Checkouts
II	Target Engine System Launch Operations
	• Propellant Loading - Fuel
	• Propellant Loading - Oxidizer
	• Fuel Transfer Malfunction
	• Oxidizer Transfer Malfunction
	• GN_2 System Charge
	• Scrub/Recycle
III	Target Engine System Post-Flight Recovery
	• Propulsion System Recovery
	• Pressurant and Propellant Dump Confirmed
	• Oxidizer or Fuel Dump Not Confirmed
	• Oxidizer and Fuel Dump Not Confirmed
IV	Target Engine System Securing
	• Decontamination
	• Preparation for Shipment

It is anticipated that the operations described herein will be monitored by trained Rocketdyne personnel on site, and in some instances Rocketdyne personnel will assist in or perform the actual operational details.

Table B-1 presents torque values applicable to assembly of components in the Target Engine System.

Table B-2 is a list of miscellaneous hardware necessary to satisfy maintenance and check out requirements on the Target Engine System.

TABLE B-1. TORQUE VALUES

Component	Torque, in.-lb
Fill and Drain Valves	
Valve	25-35
1/4-inch cap	135-185
3/16-inch cap	90-140
Squib Valves (GN_2 isolation, fuel dump, and oxidizer dump)	
Valve assembly to housing attach screws (10-32)	19-24
Service Port -- SP02 Cap	450-525
Regulator Adjust Jam Nut	180-230
Burst Diaphragm--GN_2 System	
1/2-inch B-nut to check valve (D/S)	450-525
Check valve to an swivel	450-525
Bushing to check valve (U/S)	180-230
Filter to AN bushing	420-600
Filter to burst diaphragm	420-600
Burst diaphragm to reducer union	420-600
Reducer union to aluminum housing	180-230
Service Port--SP03	135-185
Burst Diaphragm--Oxidizer System	
B-nut (oxidizer tank to 3/4-inch AN union	900-1100
3/4-inch AN union to aluminum housing	420-600
B-nut (1/4-inch fill and drain valve line)	135-185
1/4-inch aluminum manifold attach screws	61-75
B-nut (5/8-inch oxidizer line, D/S)	650-700
B-nut (1/2-inch dump line)	450-525
5/16-inch aluminum manifold attach screws	105-135

TABLE B-1. (Concluded)

Component	Torque, in.-lb
Fuel orifice to aluminum housing	420-600
Fuel orifice to bushing	420-600
Jam nut to aluminum housing	540-660
Filter to AN union	420-600
Filter to burst diaphragm	420-600
Burst diaphragm to aluminum housing	420-600
Burst Diaphragm--Fuel System	
B-nut (fuel tank to 3/4-inch AN union)	900-1100
3/4-inch AN union to aluminum housing	420-600
B-nut (1/4-inch fill and drain valve line)	135-185
1/4-inch aluminum manifold attach screws	61-75
B-nut (3/4-inch fuel line)	900-1100
Orifice to aluminum housing	420-600
B-nut (1/2-inch dump line)	450-525
Aluminum manifold attach screws	61-75
Jam nut to aluminum housing	540-660
Filter to AN union	420-600
Filter to burst diaphragm	420-600
Burst diaphragm to aluminum housing	420-600
Propellant Dump Line Plug	150-200
Service Port--SP18 and SP26	150-200

NOTES: Use backup wrenches as required to prevent overtorquing of adjacent components.

TABLE B-2. TARGET ENGINE SYSTEM SERVICING HARDWARE

Part Name	Quantity	Comment
Pressure Transducer (spare)	1	S/N 1273 (0-1000 psia)
3/16-Inch AN Back-to-Back	2	Fuel servicing
Squib Valve Connector	3	
Temperature Transducer Connector	3	
Pressure Transducer Connector	3	
Burst Disk	4	Spares for flight
Screws for Skins and Doors	10 and 10	Spares for flight
Throat Plug		
RS-14	1	
Atlas	1	
Acceleration Block	1	Spare
O-ring Kit	Various	Spares
Squib Valve (fired)	1	Checkout
RS-14 Engine Connector	1	Electrical checkouts
Four-Way Valve Connector	1	Electrical checkouts
Kyrtox Lube	1	O-ring lubricant

I. TARGET ENGINE SYSTEM PRELAUNCH CHECKOUTS

SYSTEM CONFIGURATION

TEM 1 and 2 (Fig. B-1)

TEM 3 (Fig. B-2)

CHECKOUT CONDITION

Target Engine System and Attitude Control System integrated. Skins removed from propulsion modules and aft cover removed from engine. Tests performed in checkout area with appropriate electrical and mechanical checkout gear available.

CHECKOUT TESTS

Squib Valve Checkout and Installation, per Section 4.0, Appendix A.

Transducers Checks (pressure and Temperature), per Section 5.0, Appendix A.

Pneumatic Regulator Pressure Setting, per Section 3.0, Appendix A.

System Leak and Functional Checks, per Section 6.0, Appendix A.

- Burst Disk Integrity
- Engine Propellant Valve Actuation
- System Integrity

NOTE: Checkout tests are to be performed in the order given

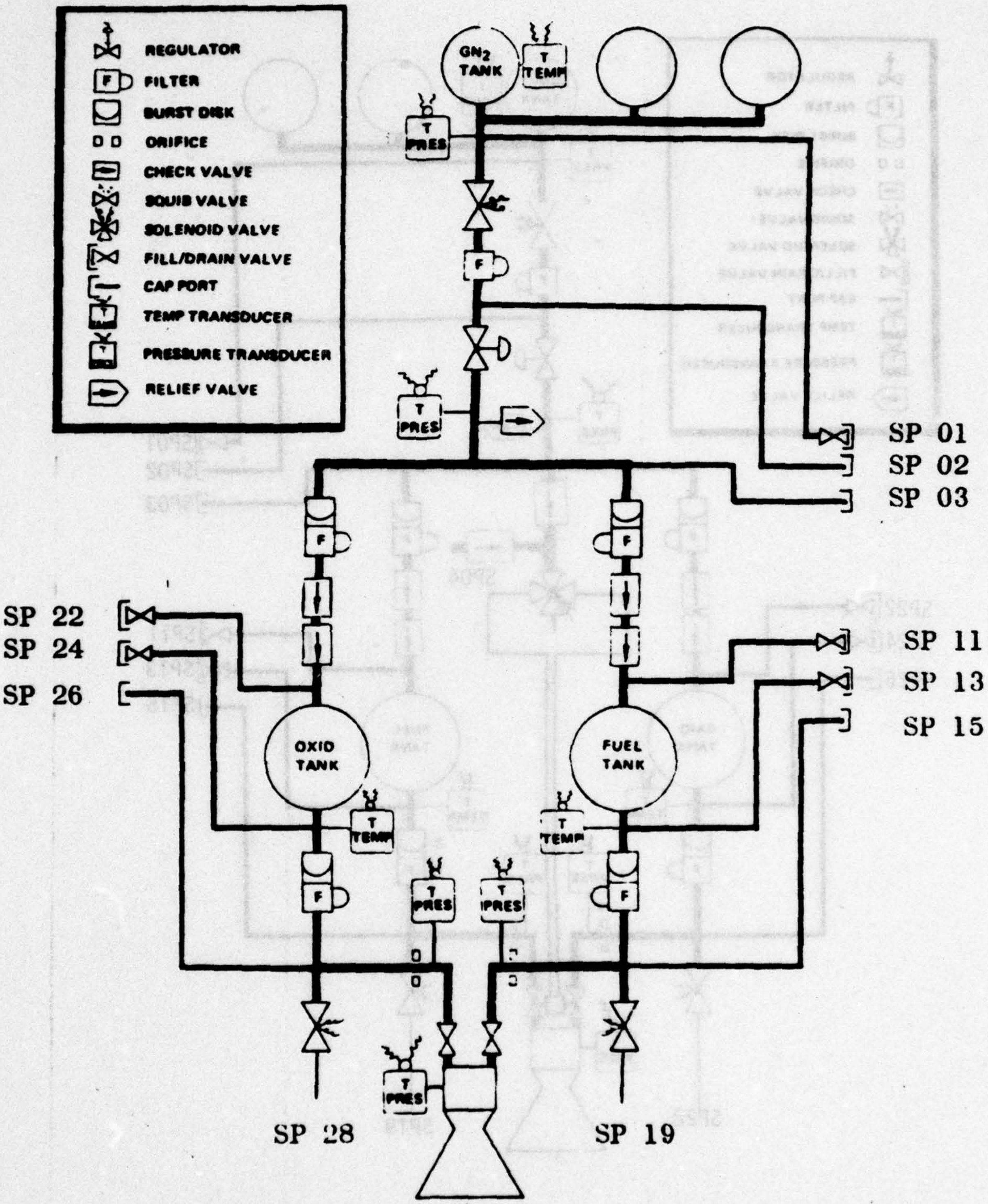


Figure B-1. TEM-1 and -2 Schematic

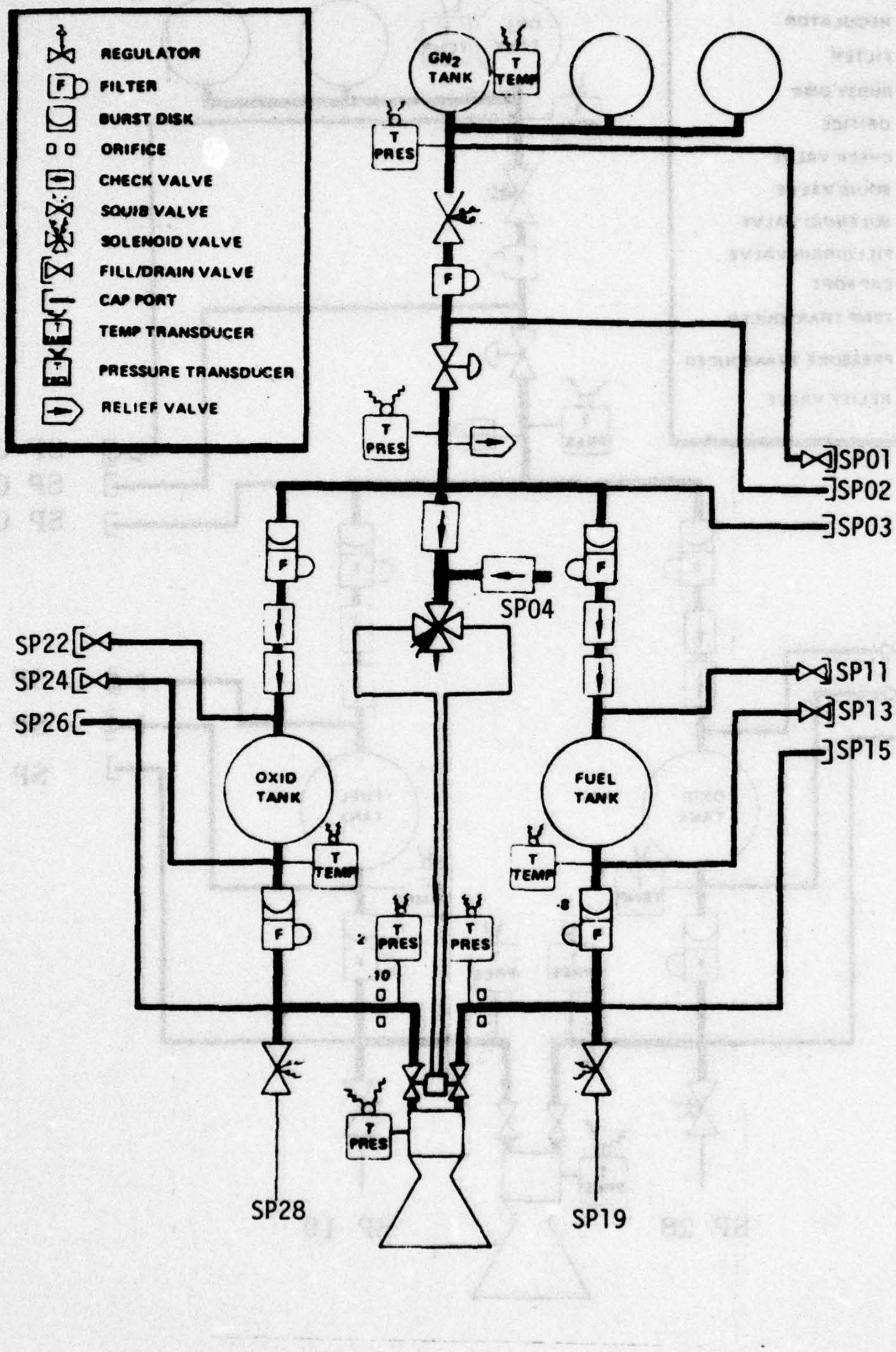


Figure B-2. TEM-3 Schematic

II. TARGET ENGINE SYSTEM LAUNCH OPERATIONS

PROPULSION SYSTEM CONFIGURATION

TEM 1 and 2 (Fig. B-1)

TEM 3 (Fig. B-2)

LAUNCH COUNTDOWN CONDITION

Vehicle stacked

Instrumentation active

LAUNCH COUNTDOWN ACTIVITY

Pressurant supply charged

Propellant NTO and MMH supplies loaded

EQUIPMENT REQUIREMENTS

Gaseous Nitrogen Supply

- 25μ filtered GN_2 per MIL-P-27401
- Supply capable to charge 3000 cu in. to 3500 psig
- Relief valve in regulated supply for GN_2 charge system - 3600 psig
- Relief valve in GN_2 leak check system - 60 ±3 psig
- Vent capability in regulated supply

Propellant (NTO and MMH) Storage/Transfer and Load

- Storage

  NTO MIL-P-26539 - nominal 100 pounds

  MMH MIL-P-27404 - nominal 65 pounds
- Transfer from storage

  To Rocketdyne-provided oxidizer and fuel service carts

  Low-pressure GN_2 transfer
- Load, propulsion supply tanks

  Via oxidizer and fuel service carts

Platform Scales (0-500 pounds, 1-pound increments, ±1/4% accuracy)

Safety Clothing - Respiratory Protection and Other Safety Equipment

Propellant

- Provided per AFM 161-30

    Chapter 9 - MMH

    Chapter 17 - NTO

Propellant Flushing/Inerting Agents

- MIL-C-81302 "Freon" - NTO Flush
- TT-I-735 Grade A Isopropyl Alcohol - MMH Flush

Fire/Hazard Control - Fixed and Mobile

Water

Fog

Deluge

1.0 COUNTDOWN/ABORT - GENERAL

Preparation for pressurant and propellant systems loading:

- System instrumentation active
- TES service doors removed

    Fuel and pneumatic

    Oxidizer

- Propellant (oxidizer and fuel) service ports are accessible (Fig. B-1 and B-2).
- Propellant oxidizer and fuel service carts have been loaded for required propulsion system requirements.
- Propellant oxidizer and fuel catch tanks will be available to trap propellant fumes from propellant service cart and TES.
- Safety clothing and equipment will be available for propellant handling/loading crew.
- Plentiful water supply with fog/deluge discharge will be available for control of propellant spill.

- The area of propellant handling and transfer must be cleared of organic and absorbent materials.
- Individual(s) serving as backup support to loading crew will be at site wearing appropriate safety equipment during propellant loading operatios.

2.0 PROPELLANT LOADING - FUEL

NOTE: Crew to perform MMH loading will have trained for handling and safeing propellant systems.

NOTE: Appropriate safety equipment will be worn by propellant crew.

NOTE: Fuel propellant loading will take place only when oxidizer propellant storage and transfer systems are secured.

2.1 Load 56 pounds of MMH per Section 7.0, Appendix A, Paragraphs 7.2.1 through 7.3.16.

3.0 PROPELLANT LOADING - OXIDIZER

NOTE: Crew to perform NTO loading will have been trained for handling and safeing propellant systems.

NOTE: Appropriate safety equipment will be worn by propellant crew.

NOTE: Oxidizer propellant loading will take place only when fuel propellant storage and transfer systems are secured.

3.1 Load 90 pounds of NTO per Section 8.0, Appendix A, Paragraphs 8.2.1 through 8.3.15.

4.0 FUEL TRANSFER MALFUNCTION

If during a propellant handling or transfer a leak is detected.

4.1 A hazardous condition warning must be made.

4.2 Propellant support crew wearing appropriate safety equipment including self contained air breathing apparatus will relieve primary crew if they are not wearing air apparatus.

4.3 Close FTU tanking valve. Isolate leak orgin.

4.4 Assure that TES fuel tank is vented at SP11.

4.5 Apply water to inert spillage.

4.6 Close TES fuel fill and drain valve at SP13.

4.7 Close "cart tank N_2 supply" valve on FTU.

4.8 Open FTU vent valve.

4.9 Retorque joint of leak origin.

- If leakage has stopped reinitiate propellant fill of engine tank.
- If decision is to Abort, detank fuel per Section 7, Appendix A, Paragraphs 7.5.1 through 7.5.20.

5.0 OXIDIZER TRANSFER MALFUNCTION

If during a propellant handling or transfer a leak is detected.

5.1 Hazardous condition warning must be made.

5.2 Propellant support crew wearing appropriate safety equipment including self contained air breathing apparatus will relieve primary crew if they are not wearing air appratus.

5.3 Close OTU tanking valve, isolate leak origin.

5.4 Assure that TES oxidizer tanking valve is vented at SP22.

5.5 Apply water to inert spillage.

5.6 Close oxidizer fill and drain valve at SP24.

5.7 Close "cart tank N_2 supply" valve on OTU.

5.8 Open OTU vent valve.

5.9 Retorque joint of oxidizer leak origin.

- If leakage has stopped reinitiate propellant fill of engine tank.
- If decision is to abort, detank oxidizer per Section 8, Appendix A, Paragraphs 8.5.1 through 8.5.20.

6.0 GN_2 SYSTEM CHARGE

- Charge GN_2 per Section 9.0, Appendix A.

7.0 SCRUB/RECYCLE

LAUNCH SCRUB occurs following propulsion system propellant loading and pressurant charging and propulsion system has been secured.

CONDITION 1

Maintain pressurant and propellant charge condition.

- Launch rescheduled for next day
- RF signal generation in vicinity of vehicle maintained at requirements for launch.
- Absence of potential of lightning strike to vehicle.
- Propulsion instrumentation active and surveillance maintained.

CONDITION 2

Vent pressurant supply but maintain propellant charge condition.

- Launch rescheduled beyond next day.
- RF signal generation in vicinity of vehicle is not maintained at requirement of launch.
- Presence of potential of lightning in vicinity of vehicle.
- System surveillance is not maintained.

LAUNCH RECYCLE

CONDITION 1

- Pick up launch countdown

CONDITION 2

- Activate instrumentation.
- Verify oxidizer and fuel inlet pressures at ambient.

  Pressure in excess of local ambient would be indicative of propellant isolation burst diaphragm failure. For this condition propulsion module would have to be removed from stacked vehicle and returned to service area for propellant removal, decontamination and system service.

With satisfactory oxidizer and fuel pressures verified, proceed to charge propulsion system pressurant supply per countdown procedure.

NOTE: Verify integrity of pressurant isolation valve as pressurant charge is initiated. Integrity established when regulated pressure measurement remains at ambient as pressurant supply tanks are charged.

If nonsatisfactory condition of pressurant isolation valve is noted, pneumatic system charge must be terminated, and GN_2 vented for valve replacement. Dump GN_2 load per Section 10.0, Appendix A. Squib valves must be validated for satisfactory condition by continuity check of squib circuit of each valve. Valves could be replaced and checked with propulsion module in stacked vehicle but decision would have to be evaluated relative to hazard of loaded propellants, access and checkout capability on site.

Verify that regulator bleed is closed.

When pressurization of propulsion system is complete, install propulsion module doors to pneumatic and fuel service panel.

III. TARGET ENGINE SYSTEM POST FLIGHT RECOVERY

PROPULSION SYSTEM CONFIGURATION

TEM 1 and 2 (Fig. B-1)

TEM 3 (Fig. B-2)

RECOVERY CONDITION

- Propulsion module mated with attitude control system (ACS) and parachute attached
- Potential hazards

  Fire/explosion

  Hazardous propellant leakage

    NTO

    MMH

  High-pressure GN_2 pneumatics and propellants if dump valves not fired.

  Impact damage - sharp edges

RECOVERY ACTIVITY

- Evaluate flight data to confirm satisfactory operation of propellant dump system.
- Safe system for pickup and transport to hazardous service area.

HAZARDOUS OPERATIONS-EQUIPMENT REQUIREMENTS

- Mobile/Transportable Supplies

  Propellant flushing/fluid

    200 gallons of water in fire-fighting system or equivalent

Gaseous nitrogen

MIL-P-27401 K bottle

0-300 psi regulated, 3 ft^3

- Fire/Explosion Control

  Water - stream, deluge, and fog

- Safety Clothing - Respiratory Protection and Other Safety Equipment

  Fire

  Propellant per AFM 161-30

  Chapter 9 - MMH

  Chapter 17 - NTO

- Recovery Vehicle

  Crane capable of lifting propulsion and ACS modules assembly - 1000-pound nominal load capability

  Cradle - to hold and secure recovered modules for transport to service area

- Vent Lines

  Fuel - 3/16-inch fitting adapter - 50-foot reinforced polyethylene

  Oxidizer - 1/4-inch fitting adapter - 50-foot reinforced polyethylene (limited service)

1.0 PROPULSION SYSTEM RECOVERY

Determine from flight data status of propellants and pressurant dump post last burn.

If data do not support full dump, propulsion module recovery activity must be related to available data and possible pressurized propellant/ pneumatic systems.

NOTE: Extreme hazard caution

Expeditious recovery of propulsion system and return of system for decontamination is necessary to minimize damage of hardware.

Personnel involved in the recovery activity shall have been trained for handling of NTO and MMH and shall wear appropriate safety equipment.

A backup team shall be available for emergency support to recovery crew.

If smoke or vapors are coming from propulsion system module, fire fighting crew only are to approach module for water fog application to module. Allow few minutes after fog application to confirm stable condition of module before proceeding to recover module.

If there is a fire in the propulsion module, all personnel are to maintain a safe distance from module. Fire fighting crew will approach module for water stream application only when fire is reduced to a stable condition. Recovery crew will proceed with recovery of module only when it is confirmed that fire has terminated.

2.0 PRESSURANT AND PROPELLANT DUMP CONFIRMED

CAUTION: Recovery crew to approach propulsion module only when absence of smoke, fumes, or fire is confirmed.

NOTE: Recovery crew to carry propellant dump closures and module lifting eye with them when going in for recovery closure.

CAUTION: Verify module position stability before beginning to work on module.

2.1 Install propellant dump line closures, depending on accessibility. If closure cannot be installed because of fitting damage, apply Kel-F sheet over end of module fitting and tape closed using Teflon tape.

2.2 Install lifting eye to module.

2.3 Bring in module lift crane and attach life cable to lifting eye.

CAUTION: Minor propellant leakage may occur in next step, wash with water on occurrence.

2.4 If because of module landing attitude propellant dump closure could not be installed in as-found condition, lift module sufficient to clear port for closure installation.

2.5 Install closure at propellant dumps.

2.6 Detach parachute.

2.7 Use crane to place module in transport cradle.

2.8 Return module to service area.

3.0 OXIDIZER OR FUEL DUMP NOT CONFIRMED

Notes of 1. and 2. applicable.

NOTE: Recovery crew should carry in vent lines, also weights or restraints to maintain line exit position on vent should be used with vent line.

CAUTION: Care must be maintained to check for propellant leakage to take appropriate action to maintain safe conditions.

3.1 Install propellant dump line closures if accessible or when accessible in subsequent steps.

3.2 Install lifting eye to module.

3.3 Bring in mobile lift crane and attach cable to lifting eye.

3.4 Lift module only to provide module stability and access to service panel close out for propellant circuit not vented.

3.5 Detach parachute.

3.6 Remove close-out panel to provide access to service panel.

3.7 Remove closure from propellant fill valve (SP13 or SP24).

3.8 Attach vent line propellant fill valve.

3.9 Stretch vent line away from module and maintain line as straight as possible. Line exit should be in cleared terrain and restrained.

NOTE: Fire/hazard crew should be situated up wind if possible and be capable of support at module and vent line exit.

3.10 Apply water fog at exit of vent line.

CAUTION: Propellant liquid/vapor will be discharged in following step.

3.11 Slowly open TES propellant fill valve (SP13 or SP24) until venting is noted from vent line.

3.12 When venting is complete, the close TES propellant fill valve.

3.13 Remove vent line from TES Propellant fill valve.

CAUTION: Vent line to be handled as hazardous until it has been decontaminated.

3.14 Install closure on TES propellant fill valve.

3.15 Use crane to place module in transport cradle.

3.16 Return module to service area.

4.0 OXIDIZER AND FUEL DUMP NOT CONFIRMED

Notes of 1., 2. and 3. applicable.

CAUTION: If both propellant systems are not dumped, pressurized propellants remain on board.

4.1 Install propellant dump line closures if accessible or when accessible in subsequent steps.

4.2 Install lifting eye to module.

4.3 Bring in mobile lift crane and attach cable to lifting eye.

4.4 Lift module only to provide module stability and access to close out panel for pneumatic and fuel service panel.

4.5 Detach parachute.

4.6 Remove doors for the pneumatic and fuel service panel.

4.7 Attach vent line to SP01.

4.8 Open TES valve at SP01, venting GN_2 from TES.

4.9 When GN_2 venting stops, close TES valve at SP01.

4.10 Install closure on TES valve at SP01.

4.11 Attach vent line to SP13, MMH fill and drain port.

4.12 Stretch vent line away from module and maintain line as straight as possible. Line exit should be in cleared terrain and restrained.

NOTE: Fire/hazard crew should be situated up wind if possible and be capable of support at module and vent line exit.

4.13 Apply water fog at exit of vent line.

CAUTION: Propellant liquid/vapor will be discharged in following step.

4.14 Slowly open TES fuel fill valve at SP13, venting MMW and GN_2 from TES.

4.15 When venting is complete, close fuel fill valve at SP13.

4.16 Remove vent line from SP13.

CAUTION: Vent line to be handled as hazardous until it has been decontaminated.

4.17 Install closure on fuel fill valve at SP13.

4.18 Remove doors on the oxidizer service panel

4.19 Attach appropriate ventline to TES oxidizer fill valve at SP24.

4.20 Stretch vent line away from module and maintain line as straight as possible. Line exit should be in cleared terrain restrained for possible movement.

NOTE: Fire/hazard crew should be situated up wind if possible and be capable of support at module and vent line exit.

4.21 Apply water flog at exit of vent line.

CAUTION: Propellant liquid/vapor will be discharged in following step.

4.22 Slowly open TES oxidizer fill valve at SP24, venting NTO and GN_2 from TES.

4.23 When venting is complete, close oxidizer fill valve at SP24.

4.24 Remove vent line from SP24.

CAUTION: Vent line to be handled as hazardous until it has been decontaminated.

4.25 Install closure on TES oxidizer fill valve at SP24.

4.26 Use crane to place module in transport cradle.

4.27 Return module to service area.

IV. TARGET ENGINE SYSTEM SECURING

PROPULSION SYSTEM CONFIGURATION

TEM 1 and 2 (Fig. B-1)

TEM 3 (Fig. B-2)

SECURING CONDITION

Propulsion module mated with ACS

Impact damage

Potential

Fire/explosion

Hazardous propellant leakage

NTO

MMH

SECURING ACTIVITY

Safing

Decontaminating

Inerting

Ship propulsion module to Rocketdyne

HAZARDOUS OPERATIONS SERVICE AREA

Hazardous propellant leak and residual disposal

NTO

MMH

FIRE/EXPLOSION CONTROL

Water - stream, deluge, and fog

PROPELLANT FLUSHING/INERTING AGENTS

- o MIL-C-83102 "Freon" NTO flush, 20-gallon, 30-psig system
- o TT-1-735 grade A isopropyl alcohol - MMH flush, 20-gallon, 30-psig system
- o Water - filtered and deionized - NTO and MMH inerting, 50-gallon system

GASEOUS GN_2 SUPPLY

25μ filtered

0-500 psi regulation

SAFETY CLOTHING - RESPIRATORY PROTECTION AND OTHER SAFETY EQUIPMENT

Fire

Propellant per AFM 161-30

Chapter 9 MMH

Chapter 17 NTO

HANDLING EQUIPMENT

Crane capable of lifting propulsion and ACS modules assembly - 1000-pound nominal.

Crane with slings must be capable of positioning assembly horizontal or vertical thrust chamber down or up.

VACUUM OVEN

Volume: 2 cu ft

Capable of

0.5 psia

160 ±10 F

POWER SUPPLY

28 Vdc

PNEUMATIC CONTROL SOURCE FOR TEM-3 MAIN PROPELLANT VALVE

100-psig GN_2
Solenoid Control, 28 Vdc

VENT LINE SET

Oxidizer - Two lines to carry Freon-diluted NTO from module to disposal area. Lines adapted to mate with TES service ports SP22 and SP24.

Each line to have shutoff valve close-coupled to fitting, making connection to propulsion system.

Fuel - Two lines to carry alcohol-diluted MMH from module to disposal area. Lines adapted to mate with TES service ports SP11 and SP13.

Each line to have shutoff valve close-coupled to fitting, making connection to propulsion system.

NOTE: Propulsion and ACS module assembly returned from post-flight landing may have

System damage
Leaks
Trapped residual propellants

1.0 DECONTAMINATION

CAUTION: Only limited crew with protective cloting to initiate decontamination. Backup crew wearing appropriate safety equipment are available to support crew performing decontamination. Fire/explosion fighting equipment will be available and ready to control hazardous conditions.

1.1 Examine module as received for leakage.

1.2 Wash any leak.

1.3 Wash profusely if leakage of both propellants is suspected.

1.4 Repeat washes until leakage subsides or is adequately diluted.

1.5 Attach crane lift/slings to module.

CAUTION: Observe for resumation of propellant leakage on next step.

1.6 Lift module from recovery vehicle cradle and raise to vertical thrust chamber down attitude.

1.7 Rest module on suitable pallet. Retain crane support if aft structure is damaged and will not support module.

1.8 Remove pneumatic and fuel and oxidizer service panels if not already removed.

NOTE: Priority for decontamination activity will be oxidizer followed by fuel unless fuel leak is present. With fuel leak initiate activity on fuel side.

CAUTION: If any spills or leakage occur in subsequent steps, condition must be considered hazardous and treated accordingly.

1.9 Decontaminate TES oxidizer system per Section 8.0, Appendix A, Paragraph 7.6.1 through 7.6.12.12.

AD-A045 318 ROCKWELL INTERNATIONAL CANOGA PARK CALIF ROCKETDYNE DIV F/G 21/8.1
TARGET ENGINE SYSTEMS.(U)
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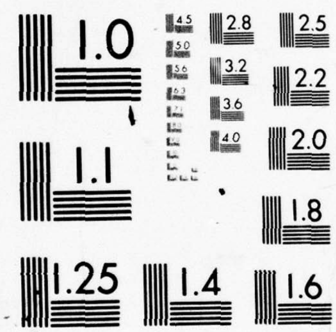


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1.10 Decontaminate TES fuel system per Section 7.0, Appendix A, Paragraphs 8.6.1 through 8.6.12.12.

2.0 Preparation for Shipment

2.1 Remove one skin panel from TES.

2.2 Disconnect electrical connectors from temperature and pressure transducers and squib valves. Store electrical cable assembly in ACS.

2.3 Demate ACS stage from TES.

2.4 Remove expended squib valves (3) and discard.

NOTE: If squib valves are in the unfired condition, install shorting plug, remove valve assembly, and destroy in a safe manner.

2.5 Install cover plates at squib valve manifolds.

2.6 Cap all exposed fittings and connections on TES.

2.7 Package TES for shipment.

APPENDIX C

TARGET ENGINE SYSTEM TEM-1 AND -2/TEM-3

PROPELLANT SYSTEM

COMPONENT	FUNCTION	ENVIRONMENT (1) PRESSURE-PSI TEM-1 AND -2	TEM-3	QTY	PART NO./CODE	COMPONENT DATA TABLE
BURST DISK	ISOLATION-OXIDIZER	250	680	2	A2060-15	C-3
	-FUEL			2	A2060-15	
FILTER	PROPELLANT-OXIDIZER			2	14204-610	C-8
	-FUEL			2	14204-610	
TANK	SUPPLY-OXIDIZER			1	305477	C-1
	-FUEL			1	305477	
VALVE - NC EXPLOSIVE ACTUATION	PROPELLANT DUMP					
	-OXIDIZER			1	NA5-260180	C-6
	-FUEL	250		1	NA5-260180	
ORIFICE	PROP FEED TRIM-OXIDIZER	250 (2)		1 TEM-3		C-12
	-FUEL	250 (2)	680	1 TEM-3		
MAIN PROPELLANT VALVE	CONTROL O&F SUPPLY	250	-	1 TEM-1 AND -2	ST2840004 RE0002	C-13
	TO THRUST CHAMBER	-	680	1 TEM-3	NA5-26312F	C-14
VALVE - FILL/DRAIN	PROPELLANT LOADING					
	-OXIDIZER	250		1	1831-16	C-10
	-FUEL			1	1831-15	C-9
VALVE - VENT	PROPELLANT LOADING					
	-OXIDIZER			1	1831-16	C-10
	-FUEL			1	1831-15	C-9
FITTING - TEST	LEAK TEST-PROP SYSTEM					
	-OXIDIZER			2		C-17
	-FUEL	250	680	2		

(1) ENVIRONMENT - OXIDIZER/NTO FUEL/MMH AND AMBIENT TEMPERATURE

(2) INCORPORATED RS-14 THRUST CHAMBER/MAIN PROPELLANT VALVE ASSEMBLY

TARGET ENGINE SYSTEM
TEM-1 AND -2/TEM-3

PNEUMATIC/PRESSURIZATION SYSTEM

COMPONENT	FUNCTION	ENVIRONMENT (1) PRESSURE-PSI TEM-1 AND -2		TEM-3	QTY	PART NO./CODE	COMPONENT DATA TABLE
TANK	SUPPLY-PRESSURANT		3000		3	TEP 1011	C-2
VALVE-NC EXPLOSIVE ACTUATION	ISOLATION-PRESSURANT		3000		1	NA5-260180	C-6
FILTER	REGULATOR SUPPLY		3000		1	14204-610	C-8
REGULATOR	PROPELLANT PRESSURANT		3000		1	553700	C-4
CHECK VALVE	ISOLATION-OXIDIZER	250		680	2	28077-8TT	C-7
	-FUEL	250		680	2	28077-8TT	
VALVE-FILL/DRAIN	LOAD/VENT-PRESSURANT		3000		1	1831-16	C-10
FITTING-TEST	LEAK TEST-HIGH PRESSURE SYSTEM		3000				C-17
FITTING-TEST	LEAK TEST-REGULATED PRESSURE SYSTEM-OXIDIZER	250		680	1		C-17
	-FUEL	250		680			
RELIEF VALVE	PROPELLANT SYSTEM OVER PRESSURIZATION - PREVENTION	250		680	1	550084	C-5
SOLENOID-4 WAY VALVE	CONTROL-MAIN PROPELLANT VALVE OPERATION	NA		680	1 TEM-3	555695	C-11

(1) ENVIRONMENT - GN_2 AND AMBIENT TEMPERATURE

TARGET ENGINE SYSTEM
TEM-1 AND -2/TEM-3

ELECTRICAL/INSTRUMENTATION SYSTEM

COMPONENT	FUNCTION	ENVIRONMENT (1) PRESSURE/MEDIA TEM-1 AND -2	TEM-3	QTY	PART NO.	COMPONENT DATA TABLE
EXPLOSIVE ACTUATION VALVES -	NOTED IN PNEUMATIC OR PROPELLANT AND ORDNANCE SYSTEMS					C-6
SOLENOID-FJUR-WAY PNEUMATIC CONTROL VALVE -	NOTED IN PNEUMATIC SYSTEM					C-5
SOLENOID-DIRECT-ACTING MPV CONTROL -	NOTED IN PROPELLANT SYSTEM					C-13
TRANSDUCER-PRESSURE	PRESSURANT-SUPPLY	3000 GN_2		1	NA5-27412-T35T	C-15
	PRESSURANT-REGULATED	250/GN_2	NA	1 TEM-1 AND -2	NA5-27412-T5T	
		NA	680/GN_2	1 TEM-3	NA5-27440-T10T	
	PROPELLANT-OXIDIZER	250/ OXIDIZER AND FUEL	NA	2 TEM-1 AND -2	NA5-27412-T5T	
	-FUEL	NA	680/ OXIDIZER AND FUEL	2 TEM-3	NA5-27440-T10	
	THRUST CHAMBER	125/ COMBUSTION PRODUCTS	360/ COMBUSTION PRODUCTS	1	NA5-27316-T2T	
TRANSDUCER-TEMPERATURE	PRESSURANT-SUPPLY	GN_2		1	NA5-27215-T3	C-16
	PROPELLANT-OXIDIZER	OXIDIZER AND FUEL		2	NA5-27215-T3	
	-FUEL			2	NA5-27215-T3	

(1) ENVIRONMENT - OXIDIZER/NTO FUEL/MMH AND AMBIENT TEMPERATURE

TARGET ENGINE SYSTEMS
TEM-1 AND -2/TEM-3

ORDNANCE SYSTEMS

COMPONENT	FUNCTION	ENVIRONMENT PRESSURE-PSI TEM-1 AND -2	ENVIRONMENT PRESSURE-PSI TEM-3	QTY	PART NO.	COMPONENT DATA TABLE
VALVE - NC EXPLOSIVE ACTUATION - DUAL SQUIB	ISOLATION-PRESSURANT	3000	3000	1	NA5-26180	C-6
	PROPELLANT DUMP-OXIDIZER	250	680	2	NA5-26180	
	-FUEL			2	NA5-26180	

TABLE C-1

PROPELLANT TANK

PART NO.	305477
MANUFACTURER	ROCKETDYNE
TYPE	SPHERICAL-BAFFLED-WELDED
MATERIAL	17-7 PH MIL-S-25043
SERVICE	1 NTO-1 680 PSI AND AMBIENT TEMPERATURE
	1 MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	1020 PSIG
BURST PRESSURE	1915 PSIG
MODIFICATION:	BAFFLE HOLES ENLARGED
WEIGHT	29 POUNDS
VOLUME	3017 IN^3

TABLE C-2

GN_2 TANK

PART NO.	TEP 1011
MANUFACTURER	ROCKETDYNE
TYPE	SPHERICAL AGE WELDED 1000 CU. IN.
MATERIAL	TITANIUM 6AL 4V
SERVICE	GN_2 AMBIENT TEMPERATURE 0-3000 PSI
PROOF PRESSURE	4650 PSI
BURST PRESSURE	9450 PSI
WEIGHT	19.3 POUNDS
VOLUME	1000 $IN.^3$

TABLE C-3

BURST DISK

PART NO.	A-2060-15 (BODY) D 1260-1 (DISK)
MANUFACTURER	FIKE
TYPE	REPLACEABLE DISK
MATERIAL	DISK: 1100-0 ALUMINUM - BODY 304 CRES
SERVICE	GN_2/NTO-1 600 PSI AND AMBIENT TEMP GN_2/MMH 600 PSI AND AMBIENT TEMP
PROOF PRESSURE (BODY)	1050 PSIG
BURST PRESSURE (BODY)	1400 PSIG
DISK RUPTURE PRESSURE	110-160 PSIG (SCORED TO WITHSTAND 90 PSI BACK PRESSURE)

TABLE C-4

REGULATOR - PNEUMATIC

PART NO.	TEP 1020 (553700 MODIFIED)
MANUFACTURER	ROCKETDYNE
TYPE	PISTON OPERATED
MATERIAL	2024T351
SERVICE	GN_2 1000/250 PSIG AND AMBIENT TEMPERATURE
INLET PRESSURE	3000 - 1100 PSIG
PROOF PRESSURE	4500 PSIG
BURST PRESSURE	15,000 PSIG
MODIFICATIONS	ELECTRICAL HEATER AND THERMOSTAT REMOVED. PRESSURE SETTING REDUCED.

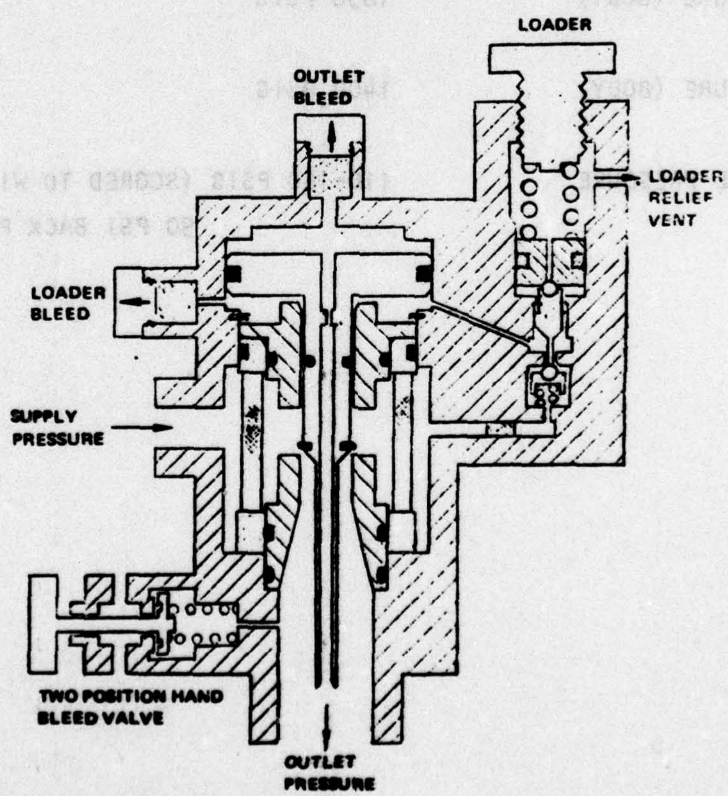


TABLE C-5

RELIEF VALVE

PART NO.	550084
MANUFACTURER	ROCKETDYNE
TYPE	PILOT OPERATED ADJUSTABLE 400-1000 PSI RESEAT > 90% OF RELIEF
MATERIAL	2024-T35
SERVICE	GN_2 680 PSI AND AMBIENT TEMPERATURE
SET PRESSURE*	900 PSI
BURST PRESSURE	3420 PSI

*TO PROTECT PROPELLANT TANKS AGAINST OVERPRESSURE

TABLE C-6

EXPLOSIVE ACTUATED VALVE

PART NO.		TEP 1025 (NA5-260180)		
MANUFACTURER		CONAX		
TYPE		DUAL SQUIB, TWO-WAY NORMALLY CLOSED		
MATERIAL		2024-T4 ALUMINUM		
SERVICE	1	GN_2	0-3000 PSI	AND AMBIENT TEMPERATURE
	1	NTO	0-680 PSI	AND AMBIENT TEMPERATURE
	1	MMH	0-680 PSI	AND AMBIENT TEMPERATURE
PROOF PRESSURE		4500 PSIG		
BURST PRESSURE		>14,000 PSIG		

SQUIB ACTUATOR (DUAL)*

TRIGGER ASSEMBLY - CONAX P/N 1617-155
PRIMER ASSEMBLY - CONAX P/N CC 21-19
740 MILLIGRAM MAX
HI TEMP POWDER - PACKED OR 70% OF BULK VOLUME
IGNITION MIX - LEAD OXIDE BORON DRY PRESSED
PRIMER SPOT - 0.002 BRIDGEWIRE DOPED LEAD STYPHNATE
NO FIRE - 0.5 AMP/30 SECOND
ALL FIRE - 2 AMP/20 MILLISECOND
SQUIB/FLUID INTERFACE LEAK CHECK 5000 PSI

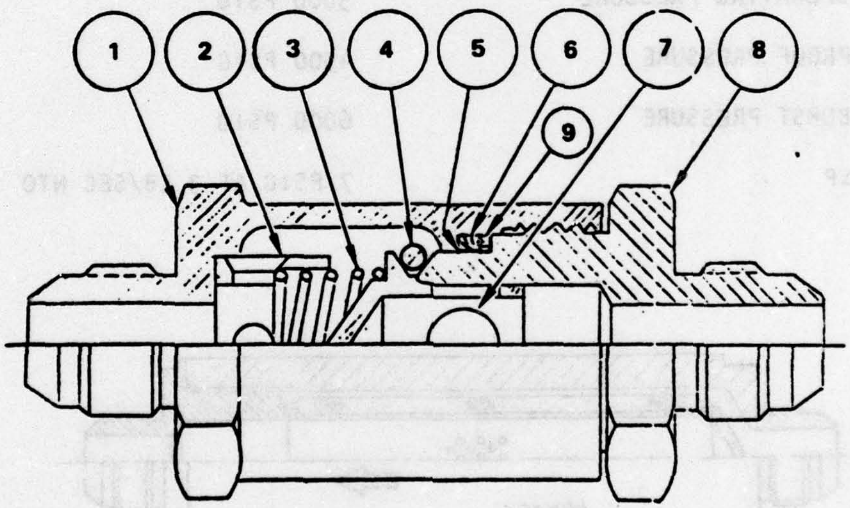
BRIDGEWIRE RESISTANCE	0.50 - 1.00 OHMS
OPERATING TIME	10 MS AT 5 AMPS

*VALVE ASSEMBLY SUCCESSFULLY PASSED A LIGHTNING STRIKE SIMULATION TEST IN SATURN II LAUNCH VEHICLE.

TABLE C-7

CHECK VALVE

PART NO.		280T1-8TT
MANUFACTURER		CIRCLE SEAL
TYPE		IN LINE - POPPET
MATERIAL		316 CRES
SERVICE	2	GN_2/NTO 680 PSI AND AMBIENT TEMPERATURE
	2	GN_2/MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE		1050 PSI
BURST PRESSURE		1400 PSI



NO.	PART NO.	DESCRIPTION	MAT'L
1.	(B)294T1	HOUSING	S.S. 316
2.	254T1	SPRING GUIDE	S.S. 316
3.	255-7	SPRING	S.S. 302
4.	K5010-20	O-RING	TEFLON
5.	10258T1	BACK-UP RING	S.S. 316
6.	12280L	GASKET	TEFLON
7.	(A)K253T1	POPPET	S.S. 316
8.	(A)K295T1	END	S.S. 316
9.	12275T1	SPACER	S.S. 316

TABLE C-8

FILTER

PART NO.		14204-610	
MANUFACTURER		WINTEC	
TYPE		IN LINE, WOVEN WIRE MESH 40 μ ABSOLUTE	
MATERIAL		304L AND 347 CRES	
SERVICE	1	GN_2	3000 PSI AND AMBIENT TEMPERATURE
	2	NTO	680 PSI AND AMBIENT TEMPERATURE
	2	MMH	680 PSI AND AMBIENT TEMPERATURE
OPERATING PRESSURE		3000 PSIG	
PROOF PRESSURE		4500 PSIG	
BURST PRESSURE		6000 PSIG	
ΔP		7 PSIG AT 3 LB/SEC NTO	

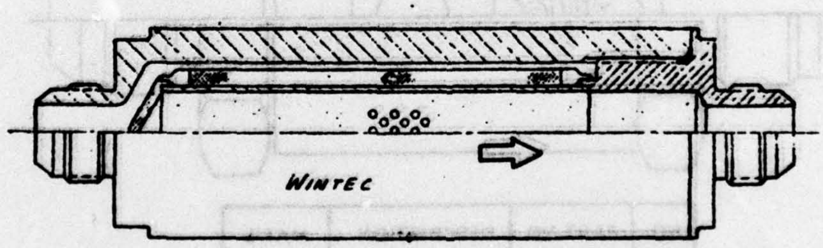


TABLE C-9

FILL/DRAIN AND VENT VALVE

PART NO.	1831-15
MANUFACTURER	PYRONETICS
TYPE	POPPET - THREAD FITTING ACTUATOR - PORT CLOSURE 3/16-INCH FITTING
MATERIAL	304L CRES
SERVICE	FILL/DRAIN MMH 680 PSI AND AMBIENT TEMPERATURE VENT MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	1200 PSIG
BURST PRESSURE	2000 PSIG

TABLE C-10

FILL/DRAIN AND VENT VALVE

PART NO.	1831-16
MANUFACTURER	PYRONETICS
TYPE	POPPET - THREAD FITTING ACTIVATOR - PORT CLOSURE
MATERIAL	304L CRES
SERVICE	FILL/DRAIN GN_2-3000 PSI AND AMBIENT TEMPERATURE FILL/DRAIN NTO 680 PSI AND AMBIENT TEMPERATURE VENT NTO 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	4500 PSI
BURST PRESSURE	7000 PSI

TABLE C-11

SOLENOID, FOUR-WAY PNEUMATIC CONTROL

PART NO.	555695
MANUFACTURER	ROCKETDYNE
TYPE	FOUR-WAY PNEUMATIC CONTROL 28 VDC
MATERIAL	356-T6 ALUMINUM CASTING
SERVICE	TEM-3 CONFIGURATION ONLY GN_2 680 PSI AMBIENT TEMPERATURE
PROOF PRESSURE	1500 PSI
BURST PRESSURE	2880 PSI

TABLE C-12

ORIFICE

PART NO.	RD 273-1013
MANUFACTURER	ROCKETDYNE
TYPE	UNION - FLAT PLATE - SHARP EDGE
MATERIAL	CRES BAR PER QQ-S-763
SERVICE	NTO-1 680 PSI AND AMBIENT TEMPERATURE
	MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	DNA
BURST PRESSURE	>6000 PSI

TABLE C-13

MAIN PROPELLANT VALVE (MOOG)

PART NO.	ST 28A0004RE0002
MANUFACTURER	MOOG
TYPE	BIPROPELLANT, SOLENOID-ACTUATED POPPET
MATERIAL	17-7 PH CRES AMS5644
SERVICE	NTO 250 PSI AND AMBIENT TEMPERATURE MMH 250 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	1000 PSI
BURST PRESSURE	10,000 PSI

TABLE C-14

MAIN PROPELLANT VALVE (HYDROMATICS)

TEM-3 ONLY

PART NO.	NA5-26312/133EDY
MANUFACTURER	ROCKETDYNE/HYDROMATICS
TYPE	BIPROPELLANT-PNEUMATIC ACTUATED-POPPET
MATERIAL	
SERVICE	NTO 680 PSI AND AMBIENT TEMPERATURE
	MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	1500 PSI
BURST PRESSURE	2300 PSI

TABLE C-15

PRESSURE TRANSDUCERS

PART NO.	NA5-27316-T2 NA5-27412-T5 AND T35 NA5-27440-T10T
MANUFACTURER	STATHAM
TYPE	ABSOLUTE PRESSURE DC-DC T2 0-200 PSI T5 0-500 PSI T10 0-1000 PSI T35 0-3500 PSI
MATERIAL	17-7 PH COND H950
SERVICE	T2 - TEM-1 AND -2 ONLY - ENGINE P_c 125 PSIA T5 - TEM-3 ONLY - ENGINE P_c 360 PSIA TEM-1 AND -2 ONLY - GN_2 250 PSI AND AMBIENT TEMPERATURE NTO 250 PSI AND AMBIENT TEMPERATURE MMH 250 PSI AND AMBIENT TEMPERATURE T10 - TEM 3 ONLY GN_2 680 PSI AND AMBIENT TEMPERATURE NTO 680 PSI AND AMBIENT TEMPERATURE MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	175% OF RATED
BURST PRESSURE	T2 5,900 PSI T5 12,200 PSI T10 13,200 PSI T35 24,000 PSI

TABLE C-16

TEMPERATURE TRANSDUCER

PART NO.	NA5-27215T3
MANUFACTURER	ROSEMONT
TYPE	RESISTANCE
MATERIAL	
SERVICE	GN_2 3000 PSI AND AMBIENT TEMPERATURE NTO 680 PSI AND AMBIENT TEMPERATURE MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	
BURST PRESSURE	

TABLE C-17

LINES AND FITTINGS

PART NO.	NUMEROUS
MANUFACTURER	
TYPE	LINES AND FITTINGS
MATERIAL	321 AND 347 CRES
SERVICE	GN_2 3000 PSI AND AMBIENT TEMPERATURE
	GN_2 680 PSI AND AMBIENT TEMPERATURE
	MON-1 680 PSI AND AMBIENT TEMPERATURE
	MMH 680 PSI AND AMBIENT TEMPERATURE
PROOF PRESSURE	DNA
BURST PRESSURE	FACTOR OF SAFETY > 4