SECTION VI

SIMULATED MISSILE TANKS

A. INTRODUCTION

The use of simulated missile (SM) tanks in place of actual missile tanks has been approved for Group I, Test Plan 5. The basic reason for the use of simulated missile tanks is that they will be able to withstand overpressure, which could conceivably result from a Propellant Loading System malfunction.

Since The Martin Company's "battleship tanks" in general duplicate the dimensional requirements of the J-1 missile, and since these tanks are available, their use has already been recommended by ADL.

We have included this section on SM tanks to specify ADL requirements as far as SM tank subsystems are concerned and to point out problems that their use imposes on the PLS tests.

The SM tank basic requirements presented in this report represent an outline of the over-all rather than the specific requirements. Preparation of detailed specifications will require full knowledge of the J-1 missile characteristics, which are not available to ADL.

A comparison of the effect of the SM tank with that of the missile tank depends mainly on the liquid oxygen boil-off associated with the tank. We feel that this problem can be solved analytically, and the solution subsequently checked by tests with the PLS and the J-1 missile.

Plans for installation of the SM tanks at OSTF are briefly outlined in paragraph B below.

B. REQUIREMENTS FOR THE USE OF SIMULATED MISSILE TANKS AT OSTF

1. General

All OSTF components should duplicate the operational equipment. This requirement has been waived to allow the use of SM tanks, but accessory equipment should duplicate the actual missile equipment. All valves, fill lines, disconnects, vent valves, etc. should exactly duplicate the missile hardware. Martin Drawing 327-0354063 has been used as a reference in the preparation of these specifications. If this drawing should be revised or superseded the following requirements must be re-evaluated.

2. Specific

a. Tank Orientation

SM tanks should be located at the same elevations as the J-1 missile tanks. Vents, fill connectors, etc. should be oriented as in the missile so that silo facilities, such as vent ducts and fill lines, are compatible with the SM tanks. The station marks of the SM tanks should be altered to coincide as closely as possible with the station marks for the missile tanks as shown in the Martin Drawing 327-0354063.

b. Tank Fitting

(1) Stage I Fuel Tank. The test configuration must resemble as closely as possible the corresponding configuration of the actual missile system. Stage I fuel tank must be equipped with the following items:

(a) A fuel disconnect installed at the same elevation and oriented as on the J-1 missile should be the same model disconnect as that intended for use on the missile.

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(b) The fuel fill line, installed between the disconnect and the tanks, should duplicate the size and configuration of the line used in the missile.

(c) Fuel drain lines and valves, which should be the same as those intended for use in the missile, should be provided.

(d) A vent valve, which should be the same as that to be used in the missile, should be provided.

(e) Insulation on liquid oxygen lines which pass through fuel tank should also be provided.

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(2) Stage I Liquid Oxygen Tank. The test configuration must resemble as closely as possible the corresponding configuration of the actual missile system. The Stage I liquid oxygen tank must be equipped with the following items:

(a) A liquid oxygen disconnect installed and oriented as on the J-1 missile. OK

(b) Liquid oxygen fill lines installed between the disconnect and the tanks. OK

(c) A liquid oxygen line to engines, valved so that the cooldown mass is the same as that for the missile system. OK

(d) Remove the cylindrical helium tank and install spherical helium tanks. OK

(e) One vent valve. OK

(3) Stage II Liquid Oxygen Tank. The test configuration must resemble as closely as possible the corresponding configuration of the actual missile system. The Stage II liquid oxygen tanks must be equipped with the following items:

(a) A liquid oxygen disconnect installed and oriented as in the J-1 missile.

(b) A liquid oxygen fill installed between the disconnect and the liquid oxygen tank.

(c) A liquid oxygen line to engines, valved so that the cooldown mass is the same as that for the missile system.

(d) A spherical helium tank.

(e) Insulation and heater strips to the fuel line which passes through the liquid oxygen tank.

(f) Two vent valves.

(4) Stage II Fuel Tank. The test configuration must resemble as closely as possible the corresponding configuration of the actual missile system. The Stage II fuel tank must be equipped with the following items:

(a) A fuel disconnect oriented as in the J-1 missile.

(b) A fuel line installed between the disconnect and the fuel tank.

(c) A vent.

(5) The Helium System. The helium system must be adapted as outlined below. These changes are to follow the design of the J-1 missile.

(a) Remove the cylindrical helium tank in Stage II liquid oxygen tank and replace with two spherical tanks. These tanks and the one mentioned below are to be identical with the actual missile tanks.

(b) Install one spherical helium tank in the Stage II liquid oxygen tank.

(c) Install helium disconnects at the missile skin for both stages.

(d) Install all internal missile helium piping except the in-flight heat exchanger.

(e) Install relief valves on the helium system.

(f) Install an antigeysering helium line.

(6) Nitrogen System. Nitrogen system - nitrogen inlet connections and lines should be built into both Stage I and Stage II to permit the operation of pneumatic valves.

c. Tank Instrumentation

(1) Stage I Fuel Tank. Stage I fuel tank should be equipped with the instrumentation listed below and illustrated in Figure VI-a.

(a) A temperature sensor (TR-101) located in the fill and drain line to measure temperature of fuel delivered.

(b) A pressure sensor (PR-112) in the top of the tank to measure ullage pressure.

(c) A liquid sensor (LSR-151) in the top of the tank above the 110%-full level.

(2) Stage I Liquid Oxygen Tank. Stage I liquid oxygen should be equipped with the instrumentation listed below and is illustrated in Figure VI-a.

(a) A temperature sensor (TR-219 and TR-220) in each fill line between the fuel tank and the liquid oxygen tank.

(b) A liquid sensor (LSR-253) located at the bottom of the tank to sense the arrival of liquid phase.

(c) A liquid sensor (LLR-251) located at the 95%-full level.

(d) A pressure sensor (PR-225) in the top of the tank to measure ullage pressure.

(e) A liquid sensor (LSR-251) located at the top of the tank above the 110%-full level.

(f) A differential pressure liquid level sensing device (LLR-251) operating over the range 0 - 110% full.

(3) Stage II Liquid Oxygen Tank. Stage II liquid oxygen tank should be equipped with the instrumentation listed below and illustrated in Figure VI-a.

(a) A liquid sensor (LSR-254) at the bottom of the tank to sense the arrival of liquid phase.

(b) A liquid sensor (LLR-252) at the 95%-full level.

(c) A pressure sensor (PR-226) in the top of the tank to measure ullage pressure.

(d) A liquid sensor (LSR-252) at the top of the tank above the 110%-full level.

(e) A differential pressure liquid level sensing device (LLR-252) to operate over the range 0 - 110% full.

(4) Stage II Fuel Tank. Stage II fuel tank should be equipped with the instrumentation listed below and illustrated in Figure VI-a.

(a) A temperature sensor (TR-102) located in the fill and drain line to measure temperature of fuel delivered.

(b) A pressure sensor (PR-113) in the top of the tank to measure the ullage pressure.

(c) A liquid sensor (LSR-151) at the top of the tank above the 110%-full level.

(5) Helium System. The helium system should be equipped with the instrumentation listed below and illustrated in Figure VI-a.

(a) A pressure sensor (PR-608) in one of the two spheres in the Stage I liquid oxygen tank.

(b) One temperature sensor in each of the two helium spheres in the Stage I liquid oxygen tank (TR-606 and TR-608).

(c) A pressure sensor (PR-609) in the helium sphere in the Stage II liquid oxygen tank.

(d) A temperature sensor (TR-607) in the helium sphere in the Stage II liquid oxygen tank.

C. THE EFFECTS OF SM TANKS ON LOADING

Most of the effects of the substitution of SM tanks can be ascribed to the difference in boil-off produced by the difference in heat transfer.

After steady state is reached, the total heat transferred to liquid oxygen contained in a thin-walled tank is approximately the same, regardless of material of construction. At steady state, the local overall coefficient of heat transfer depends mainly on the ice layer adhering to the tank and is only moderately affected by the conduction through the metal. Therefore, we need only to consider the transient cooldown condition which occurs when the liquid oxygen is introduced to the missile tank.

In transient heat flow, the ratio of the heat conducted through a body to the heat absorbed by a body is called the thermal diffusivity. For a large value of thermal diffusivity, more heat is conducted from a body in a given time than for a small value.

The initial rate of heat transfer controls the initial boil-off in a liquid oxygen tank; consequently, it controls the rate at which the ullage pressure increases. Therefore, a missile tank made of a material with a high thermal diffusivity would be expected to have a high initial cooldown rate and, consequently, a rapid ullage-pressure build-up. For example, let us compare aluminum missile tanks and stainless steel missile tanks. The ratio of the thermal diffusivity of aluminum to that of steel is 23. Therefore, the rate of cooldown for aluminum would be faster, the boil-off rate would be greater, and the ullage pressure would increase faster than for a steel tank. A detailed analysis of the transient heat flow for specific SM tanks will describe the pressure build-up and will not preclude the use of SM tanks for this phase of the testing.

The tank mass and heat capacity will affect the total amount of boil-off. The liquid oxygen transfer capability is related to the amount of boil-off. If the liquid oxygen boil-off is excessive with SM tanks, the transfer capability will be reduced. The effects of SM tanks on boil-off must be kept in mind during evaluation of the test results.

If SM tanks are supplied for tests, they must be designed so that the thermal stresses will not be excessive when liquid oxygen is admitted to the tanks.

To determine the ability of the PLS to load the prescribed amount of helium during the desired time interval requires the use of the missile helium system. Pressurization of the SM tanks with helium is not anticipated, since such pressurization is not a part of the PLS responsibility. However, the in-missile helium piping is required for the unload sequence. If this unload capability is not provided, unloading must be done with vents open, and the propellant's drain rate must be controlled manually. When no unload gas is used, manual control is necessary during the initial drain period so that a negative pressure in the missile tank ullage will be prevented. Manual control is not possible with the present control system. Furthermore, the tests have been designed to determine the adequacy of the gas storage system. Consequently, an unload cycle that uses the unload gas should be conducted. It appears that the cost of installing the missile helium piping would be negligibly different from the cost of installing auxiliary piping to supply unload gas. This is particularly true when one considers that modification of control system as well as of the missile helium piping would be required if auxiliary piping (for unload gas) were used.

The success of the loading depends on the ability of the PLS to deliver the required amounts of propellants in the given time. Any factor which influences flow should be reproduced in the test equipment. Therefore, the SM tank piping must be identical to the missile piping. Small percentage increases in line resistance might conceivably reduce the system's capability to an undesirable level. Thus, all line diameter should be reproduced faithfully; all bends and other configuration should be the same as those in the J-1 missile. All valves should be identical to the missile valves so that the flow conditions will be the same. All vents should be the same as those in the missile so that the back-pressure conditions to be experienced during transfer will be duplicated. All valves should be the same as the missile valves so that the leakage rates will be duplicated and the capability of the blanket gas system can be evaluated. In short, all of the plumbing associated with the SM tanks should be a duplicate of the J-1 missile plumbing.

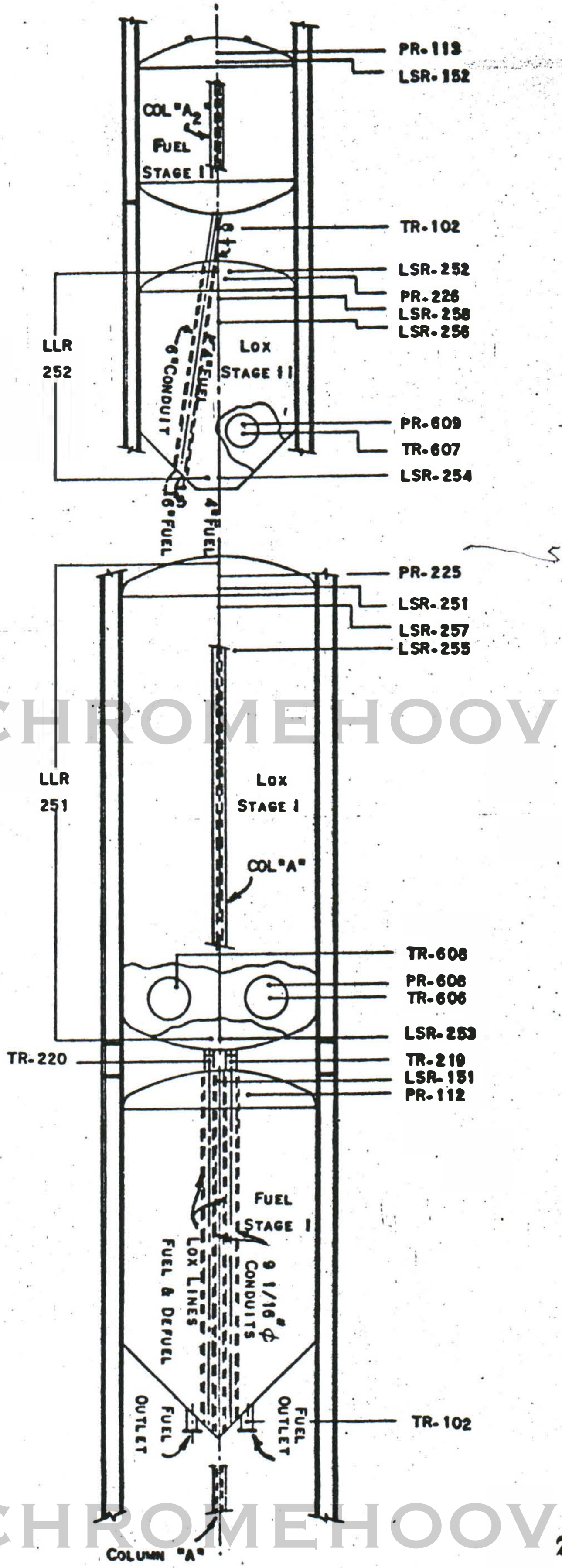

Figure VI-a
SIMULATED MISSILE TANK INSTRUMENTATION

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SECTION VII

RECOMMENDATIONS FOR

GROUP II, TEST PLAN 6

Group I, Test Plan 5 is designed to evaluate the ability of the PLS to load an operational missile. The tests listed in Section II should be adequate to check out all PLS requirements.

Loading procedures for the SM tanks (Group I, Test Plan 5) differ from those for the actual missile (Group II, Test Plan 6) in that:

1. The rate of liquid oxygen boil-off for SM tanks differs from that for missile tanks.

2. During elevation of the missile, the missile tanks will be pressurized with warm helium gas from the umbilical connections, but such elevation will not take place with the SM tanks.

3. Some of the supply requirements for nitrogen gas in the actual loading will not be duplicated in the loading of the SM tanks.

Group II, Test Plan 6 should include two over-all PLS tests, repeats of the combined PLS test of Group I, Test Plan 5, so that the effects of these differences on loading can be evaluated and the verification of the PLS design can be completed.