

DELTA  
NITROGEN TETROXIDE  
FUELING OPERATIONS

R. B. Grigsby, T. M. Cross, T. D. Rucci  
National Aeronautics and Space Administration  
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## INTRODUCTION

The Delta Program began as an interim measure in 1959 to utilize existing launch vehicles for unmanned space projects. The initial configuration combined the Thor IRBM and the Vanguard second and third stages. The first launch attempt in May 1960 failed, but this was followed three months later with the orbit of the Echo balloon, the first orbiting spacecraft visible to the naked eye. The following vehicles, including that which launched TELSTAR, the first active communications satellite, were successful and NASA elevated the Delta Program to a permanent status. Since that time, the launch vehicle configuration has been periodically upgraded from a 100-pound synchronous orbit payload in 1960 to the present 2000-pound synchronous orbit capability. The Delta evolution is shown in Figure 1.

At the present time Delta 140 (the one hundred fortieth Delta) is being prepared to launch a Japanese experimental communications satellite (BSE). Delta vehicles are also launched at Vandenberg Air Force Base in California for polar launches such as required by the Nimbus andITOS weather satellites.

Today the majority of the Delta missions are reimbursable launches for commercial companies such as RCA, Intelsat, and Western Union; for foreign governments like the Japanese BSE; or for other U.S. government agencies, e.g., NOAA, the weather bureau. Thus, the program has progressed from the research and development phase to one of applications, where the

spacecraft are used in everyday life for communications, weather, earth resources, etc.

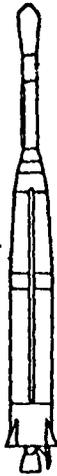
The Delta second stage nitrogen tetroxide fueling system, like the parent Delta vehicle, has undergone an evolutionary process to reach the present configuration, which will be discussed here. For instance, the origin of the propellant trailers even precedes the Delta Program to the Thor-Able Program of the 1959 timeframe. At that time and during the early portion of the Delta Program, the propellants used were red fuming nitric acid and Unsymmetrical Dimethyl Hydrazine (UDMH).

The original Delta second stage engine was a modified Aerojet Vanguard second stage engine system. It was replaced with the Aerojet Transtage engine which required that the propellant loading system be modified for  $N_2O_4$  and A50. The present second stage engine, a derivation of the TRW Apollo LEM descent engine, also utilizes the same propellants.

Other modifications to the loading system have been made to simplify it to meet more stringent safety criteria, and to assure that the surrounding environment is protected. Particular emphasis has been placed on assurance that the spacecraft environment is protected from the toxic  $N_2O_4$  fumes.

The following will describe the  $N_2O_4$  fueling system and the equipment used to insure the protection of the environment.

# DELTA HISTORY



**DELTA**  
1960  
45 kg  
(100 lb)



**DELTA A**  
1962  
68 kg  
(150 lb)



**DELTA B**  
1962  
68 kg  
(150 lb)



**DELTA C**  
1963  
82 kg  
(180 lb)



**DELTA D**  
1964  
104 kg  
(230 lb)



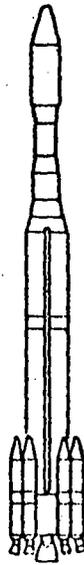
**DELTA E**  
1965  
150 kg  
(330 lb)



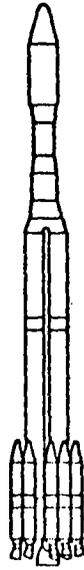
**DELTA J**  
1968  
263 kg  
(580 lb)



**DELTA M**  
1968  
356 kg  
(785 lb)



**DELTA M-6**  
1969  
454 kg  
(1,000 lb)



**DELTA 904**  
1971  
635 kg  
(1,400 lb)



**DELTA 2914**  
1972  
703 kg  
(1,550 lb)



**DELTA 3914**  
1975  
907 kg  
(2,000 lb)

## N<sub>2</sub>O<sub>4</sub> TRANSFER SYSTEM DESCRIPTION

The Delta second stage propellant loading system consists of fuel (A50) and oxidizer (N<sub>2</sub>O<sub>4</sub>) transfer systems. These two systems are essentially the same in design and function. In keeping with the symposium topic, only the N<sub>2</sub>O<sub>4</sub> transfer system will be considered in this paper.

Both are pressure fed, closed systems which utilize gaseous helium, a storage tank pressurant, for liquid transfer. A closed system, for the purpose of this paper, is defined here as a system in which all toxic liquid and vapors are contained within the system and all venting is accomplished through scrubbers containing a neutralizing solution. The transfer systems are both manually and remotely controlled during loading operations. Manual control is accomplished at the propellant transfer units (PTU's) and upper mobile service tower (MST) levels. Remote operation of PTU and MST valves is controlled from the propellant loading console (PLC) located in the blockhouse.

The N<sub>2</sub>O<sub>4</sub> transfer system consists of the following major components:

- a. Mobile Trailers (PTU's)
- b. Ullage Tank
- c. Scrubber
- d. Bubbler Tank

## SYSTEM OPERATION

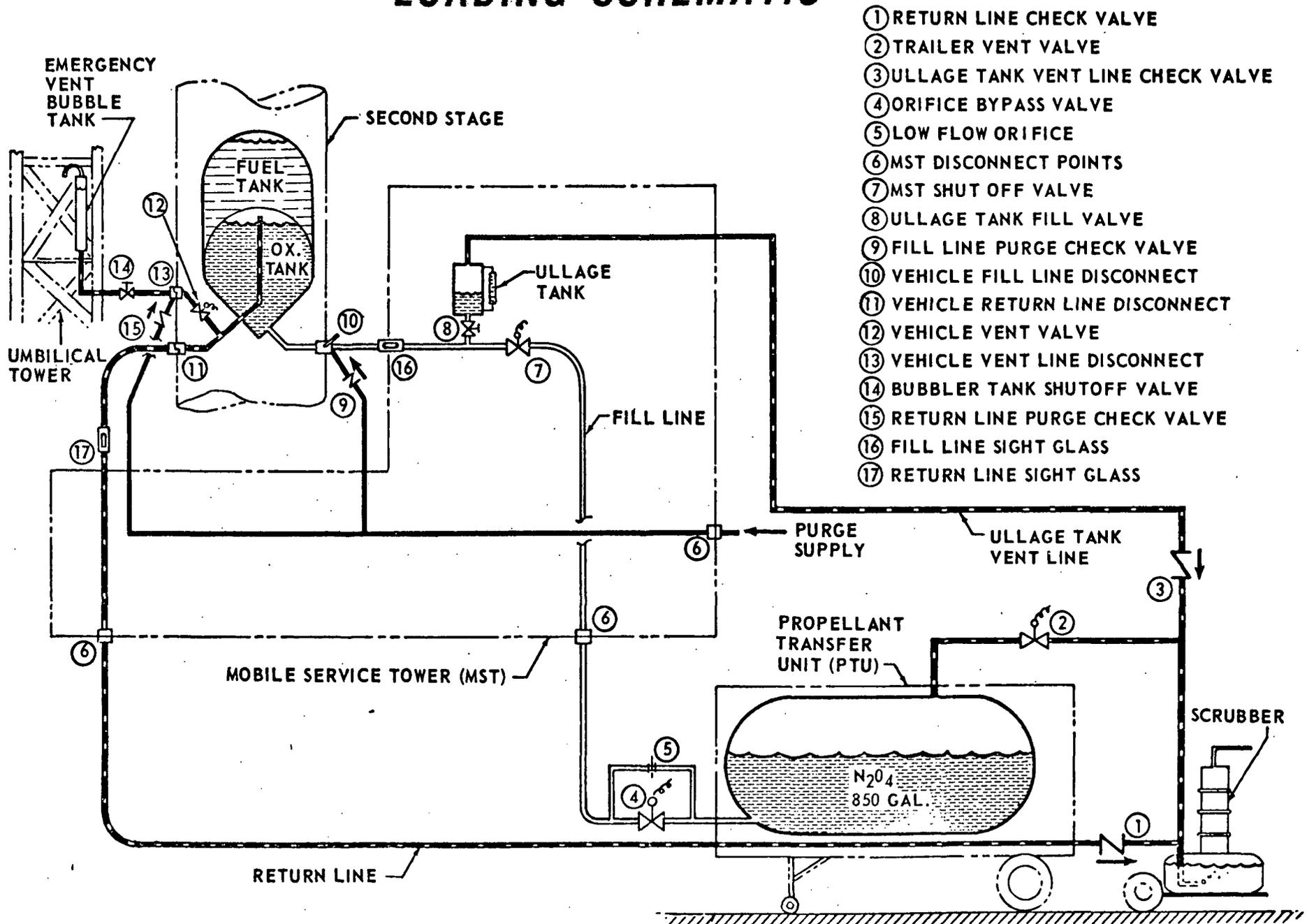
The second stage  $N_2O_4$  loading system uses helium as a storage tank pressurant for propellant transfer. During a loading operation the storage tank is pressurized to 150 psig and an initial flow rate of 4 to 5 gpm established. This flow rate is maintained through the low flow orifice until all ground and vehicle lines have been wetted and verified not leaking. At this point the orifice bypass valve (4)\* is opened and the flow rate increases to approximately 20 gpm. When the vehicle tank is 95% full, a slow fill of 5 gpm is then initiated by closing the orifice bypass (4)\* and filling until liquid is seen in the return line sightglass. The MST shutoff valve (7)\* is closed to stop propellant flow into the vehicle.

To obtain the correct vehicle tank gas ullage volume, a calculated amount of liquid  $N_2O_4$  is drained back into the ullage tank. This allows for thermal expansion of the vehicle propellant between loading and liftoff.

In order to drain this ullage tank the PTU supply tank is vented by opening valve (2)\* through the oxidizer scrubber which neutralizes the contaminated gas. The vehicle is then isolated from the fill line by closing valve (10)\* and the ullage tank liquid is drained back down the tower into the PTU supply tank by opening valves (7)\* and (4)\*. Both the fill and return lines are then purged out and disconnected at vehicle points (10)\* and (11)\*.

\*See Schematic

# DELTA ROCKET SECOND STAGE PROPELLANT LOADING SCHEMATIC



## SAFETY PRECAUTIONS

A typical propellant loading begins with Pad Safety clearing a 600-foot radius around the launch pad on which the loading is to be carried out. Only fire, medical, and SCAPE support personnel are allowed within this area during propellant flow and usually take up a position approximately 500 feet west of the mobile service tower (MST). Manual  $N_2O_4$  loading operations at both the PTU and upper MST levels are carried out by personnel dressed in SCAPE. The "buddy system" is used at all times and the SCAPE crews are continuously monitored by a network of remotely controlled TV cameras. In addition, constant voice communication is maintained between blockhouse and SCAPE personnel. Fuel and oxidizer loading is controlled by a blockhouse test conductor and usually takes four to five hours.

Prior to  $N_2O_4$  loading, the vehicle and transfer lines are leak checked with helium to insure that they will not leak liquid which could drip onto flight hardware. Drip shields are installed beneath the second stage and vehicle propellant lines to protect the first stage from drip damage in the event a leak would develop during loading. Neutralizer solution is also provided in the second stage area for washing off tools and treating drip areas. High capacity water hoses for major spill control are located at the PTU and upper MST levels. Fortunately, Delta has never had a major spill.

Throughout  $N_2O_4$  loading, SCAPE personnel are constantly watching for visible evidence of leakage as well as monitoring an in-place toxic vapor detector for leakage past the rocket engine flow control valve. Loose hardware and tools are dipped in a bucket of neutralizer before use on the fuel system. At the completion of  $N_2O_4$  loading, SCAPE personnel dip their gloves in neutralizer and shower in their suits before proceeding into fuel loading. In addition, Pad Safety "sniffs" the area around the  $N_2O_4$  PTU and second stage for possible toxic fumes before giving permission to proceed with fuel loading or opening the launch pad for normal work.

## TOXIC VAPOR TREATMENT

Toxic vapor treatment on the Delta Program has evolved from direct atmospheric discharge in the early part of the program to complete containment and chemical treatment of all toxic vapors. The thrust toward full containment was initiated by several factors, the most important of which, in their chronological order, are payload protection, personnel safety, and ecology. A water scrubber was initially used to reduce the greatest concentration of vapors which occurs when the PTU supply tank is vented. This scrubber satisfied most toxicity requirements for a number of years. However, increased payload and safety restrictions necessitated the replacement of the water scrubber with the chemical one now in use. The following paragraphs describe toxic vapor treatment at the major system component level.

N<sub>2</sub>O<sub>4</sub> PTU. The oxidizer PTU is filled with N<sub>2</sub>O<sub>4</sub> at the fuel storage area on the Cape. The PTU is filled to within one percent (8.5 gallons) of overflow. A blanket pressure of 5 to 10 psig helium is then placed on the PTU supply tank until it is raised to 150 psig for transfer to the vehicle. After propellant transfer the supply tank is vented down to a blanket pressure of again 5 to 10 psig, then disconnected from the MST and scrubber. It is then transported back to the fuel storage area to be refilled for the next launch. The PTU dates back to the 1958 era and has undergone many

improvements since then. Most notable is the addition of the scrubber and chiller units. Improved sealing and the reduction in leakage paths have also resulted in its improved reliability. The PTU supply tank is mounted inside of a catch tub which is designed to hold the entire tank contents should it rupture.

Transfer Lines. All propellant transfer lines are purged with helium for several minutes after use and before being disconnected from the second stage and MST. The purging insures that all liquid  $N_2O_4$  is blown back into the PTU supply tank and toxic vapors routed to the scrubber for treatment. Quick disconnect fittings installed in the transfer lines at the second stage interface insure against loss of toxic vapor or liquid to the atmosphere. Hand valves installed in the transfer lines near the MST/PTU connect point provide the same insurance at ground level. A caution sign is placed on the transfer lines after they have disconnected as precaution against inadvertent opening or disconnection of quick disconnects and hand valves. A slight helium blanket pressure is left on the lines between launches.

$N_2O_4$  Scrubber. The Delta  $N_2O_4$  loading system is designed and operated in a manner so as to minimize the venting of toxic vapors to the atmosphere. To accomplish this all vapors are routed to a chemical scrubber before escaping to the surroundings. The requirement for minimizing the venting of reactive vapors had its origin more out of the protection of sensitive payloads than environmental or safety aspects. With increased emphasis on environmental protection, the system can meet essentially any discharge requirement by reducing the flow rate through the scrubber.

The  $N_2O_4$  scrubber was manufactured by the Peabody Engineering Corporation of Stamford, Connecticut, for the McDonnell Douglas Astronautics Company. Design specifications were that the scrubber "should be capable of reducing 115,030 ppm  $NO_2$  down to 500 ppm from 400 scfm for 15 minutes." This value represents the maximum  $NO_2$  concentration and supply tank vent flow rate; however, actual concentration and vent down rates are considerably less. The scrubber is a two stage design utilizing five percent sodium bicarbonate solution as a vapor neutralizer.

It is a mobile unit which allows for easy transfer from one launch pad to the other as well as permitting it to be towed to a contaminated waste disposal area for draining. The unit stands approximately twelve feet high and eight feet long. It consists of a 250 gallon neutralizer holding tank at the base and a vertical spray column made up of four cylindrical spray nozzle tray sections which are mounted one on top of the other. An electric pump forces neutralizer from the holding tank to five nozzles located in the spray column at 15 gpm and 20 psig.

$N_2O_4$  fumes from the PTU supply tank, vehicle oxidizer tank, and the ullage tank, as well as from other sources, enter the scrubber through a header located at the top of the holding tank. As the vapors migrate toward the spray column they are partially neutralized by the sodium bicarbonate liquid solution in the first stage of scrubbing. Next, vapors pass through the cylindrical nozzle tray sections where the toxic concentration is reduced in stages until an acceptable level is reached for release to the atmosphere.

Bubbler Tank. After completion of fuel and oxidizer loading the  $N_2O_4$  scrubber is disconnected from the MST and PTU and removed from the launch pad area in order to protect it from rocket motor exhaust at liftoff. In its place a bubbler tank on the umbilical tower provides for toxic vapor treatment until launch. The bubbler tank is essentially a six-inch diameter piece of stainless steel pipe six feet long. It is filled with a 5% solution of sodium bicarbonate. Vapors from the second stage  $N_2O_4$  tank enter the bottom through a diffuser and migrate upward toward a vent located on the end cap at the top. Vent flow rates and volumes are low and experience with this unit indicates no detectable toxic vapor in the area of the bubbler tank vent. This method of venting is only used for  $N_2O_4$  tank pressure level adjustment or in case of an emergency vent. A typical pressure adjustment operation due to  $N_2O_4$  expansion in the tank would result in venting approximately 150 sci of  $N_2O_4$  vapor through the bubbler tank, an amount easily neutralized by this technique. The bubbler tank solution is checked for sodium bicarbonate concentration after every launch.

## CONCLUSION

Environmentally speaking, the payload requirements for emission control are more stringent than those allowed by various safety and environmental organizations. The present sodium bicarbonate scrubber meets these requirements at Complex 17. The elaborate safety precautions surrounding a Delta propellant loading operation are for personnel safety because of the potentially high explosive yield of  $N_2O_4$  and Aerozine 50 when they are brought in close proximity to one another.