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MODIFICATION AND DEVELOPMENT OF
THE EXTERNAL TANK HYDROGEN VENT UMBILICAL SYSTEM
FOR THE SPACE SHUTTLE VEHICLE

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ABSTRACT

This paper describes the design and development of a new T-0 lock and secondary release mechanism (Figure 1) which is being introduced to the ET Hydrogen Vent Umbilical System (Figure 2) for the next launch of the Space Shuttle Vehicle (Figure 3). Critical analysis of the system in early 1986 indicated the need for an improvement in the secondary release system. The new T-0 lock increases the clearance with the vehicle during secondary disconnect and is described in this paper.

INTRODUCTION

As the Space Shuttle lifts off at Kennedy Space Center, it has a liftoff drift (Figure 4) which is generally in a north direction. The ET hydrogen vent umbilical system is attached to the external tank (ET) with a pyrobolt and disconnects and falls away at liftoff (T-0). It takes approximately 2.7 seconds for it to fall to its retracted position. During this time the vehicle drifts such that the left solid rocket booster (SRB) moves towards the falling ET hydrogen vent line. Analysis indicated for worst case of secondary disconnect (a simple lanyard disconnect with vehicle rise) actual contact with the SRB could occur. In order to provide adequate clearance a T-0 lock was designed and added to the secondary system to limit the amount of vehicle rise before lanyard release thus providing adequate clearance to the drifting vehicle.

DISCUSSION

With the existing system, the secondary release lanyard employed a tracking arm allowing for prelaunch motion and simply fell away from the vent line during retraction unmanaged. As such during a secondary release the carrier plate (vehicle) would have to lift as much as one meter in order to effect a secondary release. This permitted the SRB to drift closer to the normal

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centerline of the ET (GH₂) vent line before disconnect due to the additional time to effect disconnect from the vehicle, and drift toward the vent line.

In order to solve this problem, two new features were incorporated into the system:

1. A T-0 lock was devised which would lock the weight end of the secondary release lanyard. This would limit the carrier plate rise to approximately 18 cm in order to accomplish a secondary disconnect.
2. A T-0 dropweight system was added to take up the slack of the secondary release lanyard.

Developmental testing of the new system was successfully completed on October 6, 1987 and the new system was installed on Pad B of Launch Complex 39 in December, 1987.

A primary disconnect has never failed to function; however, this new system provides a secondary release system with improved performance.

An SRB simulator was designed for clearance evaluation testing at the Launch Equipment Test Facility. This SRB simulator consisted of an adjustable position sector of SRB segments. It was adjusted to a worst-case drift position prior to the secondary disconnect. During disconnect and retract, the clearance was measured by means of multiple cameras, three fish reel deflectometers on different axes. For close clearance measurements (less than 30 cm), a laser measurement system was designed. As a back up to the laser system, monofilament nylon lines were employed approximately 15 cm from the SRB moldline. The laser beams and monofilament lines were not broken during the test. Test results indicated minimum clearance with the new secondary release system was 46 cm.

A more detailed description of the new secondary release system follows:

New Secondary (Backup) Release Mechanism. The secondary release mechanism is designed to increase the reliability of the ET vent system by providing a secondary disconnect function and a secondary latching function. A pair of 1.1 cm diameter lanyards connects the ground umbilical carrier plate (GUCP) to the spreader bar assembly attached to the underside of the flexhose support. Connected to the ends of the spreader bar is a short 1.4 cm diameter cable with a floating snatch block in the middle. A 1.6 cm diameter cable is routed from the snatch block assembly

through a system of sheaves to the T-0 lock assembly and a drop weight. The system is attached to the 58.2 m level of the fixed structural platform at Pad B up to the upper level where the T-0 lock is located. A 180 kg dropweight located under the T-0 lock keeps the cable taut before disconnect and takes up the slack in the cable after disconnect. After the dropweight has fallen, it is prevented from rising by a ratcheting mechanism, thus containing the ventline within the structure, should the primary latching system fail. The T-0 lock contains an 8.7 cm diameter by 1.6 m serrated rod which rests on the dropweight. This rod slides up and down inside the guide tube as the dropweight moves up and down with vehicle excursions. (See Figure 1). At T-0, when the ground umbilical carrier plate pyrotechnic separator is initiated, the T-0 lock pyrotechnic separator is also initiated, releasing the spring-loaded locking forks which lock the serrated rod in place. If the GUCP pyrotechnic separator fails, the vehicle continues to lift the carrier plate, and since the T-0 lock serrated rod prevents the dropweight from rising, the cable tension increases sufficiently to mechanically disconnect (break the pyrobolt) freeing the carrier plate from the ET. The length of the dropweight cable is adjusted by means of three cable clips located at the top end of the cable. The system is designed to allow approximately 1.9 cm of cable feedout prior to the secondary disconnect at approximately 18 cm of vehicle rise. The T-0 lock is contained in a protective enclosure, with hinged doors on either end and a removable cover.

BACKGROUND

The ET hydrogen vent umbilical system (Figure 5) provides the following major functions:

- o Vents GH_2 from the hydrogen tank to the fixed service structure gaseous hydrogen venting system during and after LH_2 loading via a vacuumed double-walled, stainless steel vent pipe and vacuum-jacketed flex hoses.
- o Provides a vent line pivot mechanism that permits the GH_2 vent line to track the Space Shuttle ET while it's connected to the ground umbilical carrier plate.
- o Provides release, retract, and latchback mechanisms such that, at vehicle lift-off, the vent line assembly and the ground umbilical carrier plate are disconnected from the ET and dropped to a secured and latched-back position, clearing the vehicle lift-off path.

- o Provides structural support and bulkheads for various pneumatic and electrical lines routed from the FSS* and the fixed structural platform to the ground umbilical carrier plate.

Withdrawal Mechanism. The withdrawal mechanism consists of a 680 kg withdrawal weight with wire-rope cable assemblies, guide sheaves, shock absorbers, and support structure. The withdrawal weight assembly is approximately 1.3 m high, 48 cm wide, and 15 cm deep and is a prefabricated steel shell filled with lead. The withdrawal weight is located at the back of the haunch and is mounted vertically between the 67 m level and the 63 m level (Pad B) of the fixed structural platform.

Two cable assemblies attached to the weight are routed over two guide sheaves in the rear of the haunch and are connected to the pivot arm. The suspended withdrawal weight exerts a constant 680 kg tension on the pivot arm, and subsequently on the vent line; and at T-0 when the ET umbilical carrier plate pyrotechnic separator is fired, the 680 kg tension pulls the vent line and carrier plate clear of the vehicle lift-off path as the vent line and carrier plate drop into the deceleration unit. Shock absorbers are mounted at the bottom of the withdrawal weight guide structure to absorb the energy of the dropping weight. An air-motor-driven winch is used to raise and reset the withdrawal weight.

Deceleration Unit. The deceleration unit is a mechanism used to absorb the rotational kinetic energy of the pivoting vent line and to latch it in a secured position. The unit is located under the haunch on the 58.2 m level of the fixed structural platform. The major element of the deceleration unit is a tension shock absorber with a 94 cm stroke capable of absorbing 3.457 mkg of energy.

The rod end of the vertically mounted shock absorber is attached to a guide sheave assembly through which a wire-rope cable is routed. The cable is routed to guide sheaves under the 61 m level, crossing the drop path of the vent line. The routing geometry of the cable allows the falling vent line to be decelerated and stopped approximately 2.3 m after its contact with the cable. A mechanical latching device secures the vent line in the retracted position. Should the deceleration shock absorber fail to move after the initial contact of the falling vent line into the cable assembly, a frangible link within the cable assembly will break, allowing the vent line motion to continue until latching is achieved. Tieback brackets for the vent line bridle cables are provided at the top of the

*Fixed service structure (FSS).

deceleration unit for use when the vent line is in a latched-back position. The cables are used as safety restraints during prelaunch operations.

Vent Line Assembly. The vent line assembly connects the ET ground umbilical carrier plate to the hydrogen vent system on FSS. It provides for continuous venting of the ET hydrogen tank during and after LH₂ loading and supports the pneumatic lines and umbilical interface. The vent line assembly consists of two vacuum-jacketed sections: an aft flex hose and a forward flex hose (with a double-wall vacuum hard line subassembly in between).

The aft flex hose has a 25 cm inside-diameter pipe size and is approximately 7.3 m long. This flex hose makes the connection between the hard line subassembly and the facility vent line interface. The forward flex hose has a 20 cm inside-diameter pipe size and is approximately 1.2 m long. It makes the connection between the hard line subassembly and the ground umbilical carrier plate.

The hard line subassembly is made up of a 20 cm diameter inner and a 51 cm diameter outer jacket and is approximately 7.6 m long. The aft end of the vent line is supported by the pivot arm located in the haunch. The pivot arm and withdrawal mechanism allow the line to be retracted approximately 60 cm away from the vehicle and rotated downward approximately 90° to the retracted position. The flex hose support mandrel is attached to the hard line near the pivot. This mandrel prevents the aft flex hose from exceeding the minimum bend-radius limit during vertical rotation of the vent line.

The forward flex hose support bracket is located near the outboard end of the hard line. This support limits the movement of the forward flex hose during rotation of the hard line after umbilical disconnect. The support has a saddle attached to its lower edge to engage the arresting cable of the deceleration unit.

A gimbal fitting mounted at the outboard end of the hard line provides lugs for attachment of the bridle cables and line-handling cables. The bridle cables transfer the weight of the vent line assembly to the vehicle via the ground umbilical carrier plate. This prevents tension loads from being applied to the forward flex hose. The gimbal provides equalization of tension in the bridle cables, regardless of vehicle movement or misalignment.

Bridle Support. The bridle support provides a tension link between the ground umbilical carrier plate and the forward end of the vent line assembly hard line and alleviates tension loading of the forward flex hose. Wire cable assemblies attach to both sides of the ground umbilical carrier plate and to the gimbaled fitting at the forward end of the vent line assembly hard line. The gimbaled fitting allows for vehicle motion during wind and loading conditions.

Flex Hose Support. The flex hose support restrains the ground umbilical carrier plate end of the vent line assembly from recoiling at T-0 release. A saddle on the lower side of the flex hose support engages with the deceleration unit arresting cable, and a tab engages with the deceleration unit ratchet pawls that secure the vent line in a latched position.

Umbilical Carrier Plate Assembly and GUCP Pyrotechnic Separator. The umbilical carrier plate assembly and GUCP pyrotechnic separator form the interface connection between the Shuttle ET and the hydrogen vent umbilical system (see Figure 5). The carrier plate has two feet at the bottom that rest on pins on the ET. The GUCP pyrotechnic separator near the top center completes the attachment of the carrier plate to the ET. THE GUCP pyrotechnic separator is initiated at T-0 and is the primary disconnect. In the event the GUCP pyrotechnic separator fails to initiate, the secondary release lanyard (attached to two tabs near the top of the carrier plate) is the secondary disconnect. At disconnect, the vent line assembly pulls the carrier plate away from the ET, the feet at the bottom roll on the pins of the ET until unlock rotation is achieved, and the carrier plate completes its separation from the ET. The hydrogen vent umbilical side of the carrier plate has hard connections with the pneumatic lines and the electrical cables that are routed on the top of the vent line to the FSS facility interfaces. The ET side of the carrier plate has quick-disconnect fittings that interface with various systems of the ET.

CONCLUSION

An improved secondary release system has been successfully designed, developed, qualified and introduced for the ET (GH₂) Vent system for the Space Shuttle Vehicle Ground Support. In the unlikely event of a primary disconnect system failure, it provides secondary disconnects with assurance of adequate vehicle clearance.

ACKNOWLEDGMENT

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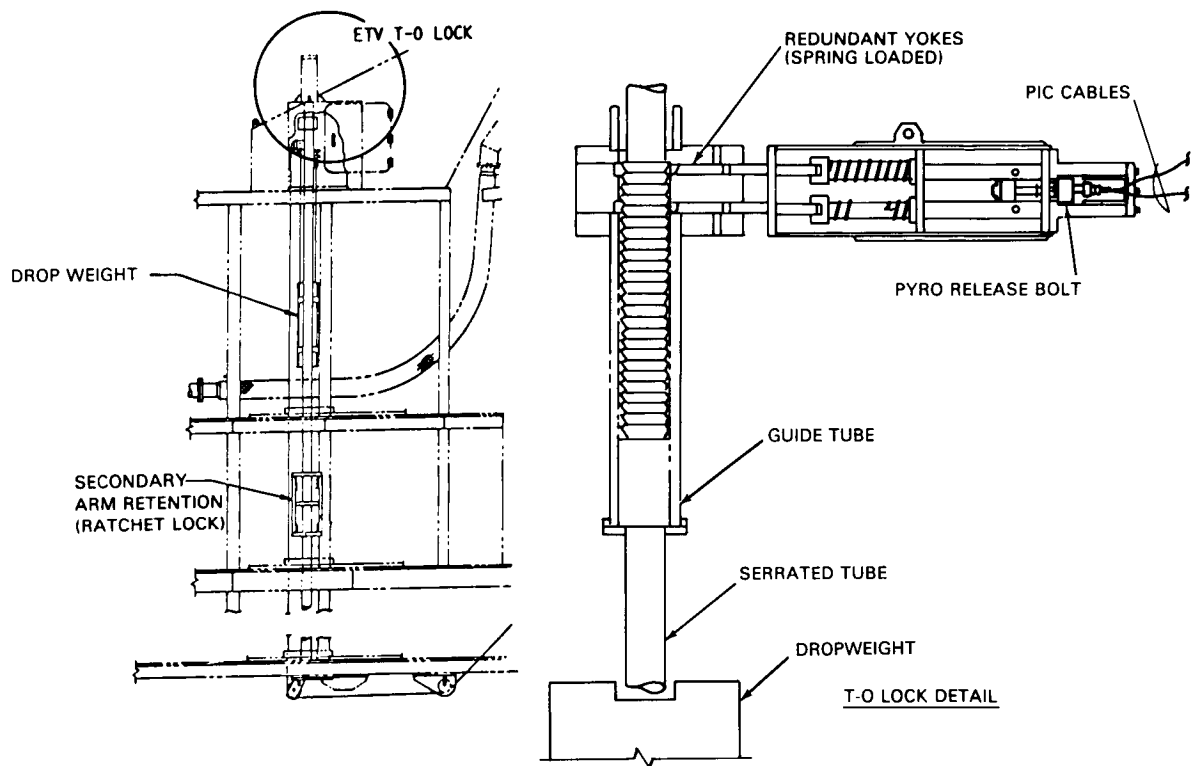


FIGURE 1: NEW T-O LOCK

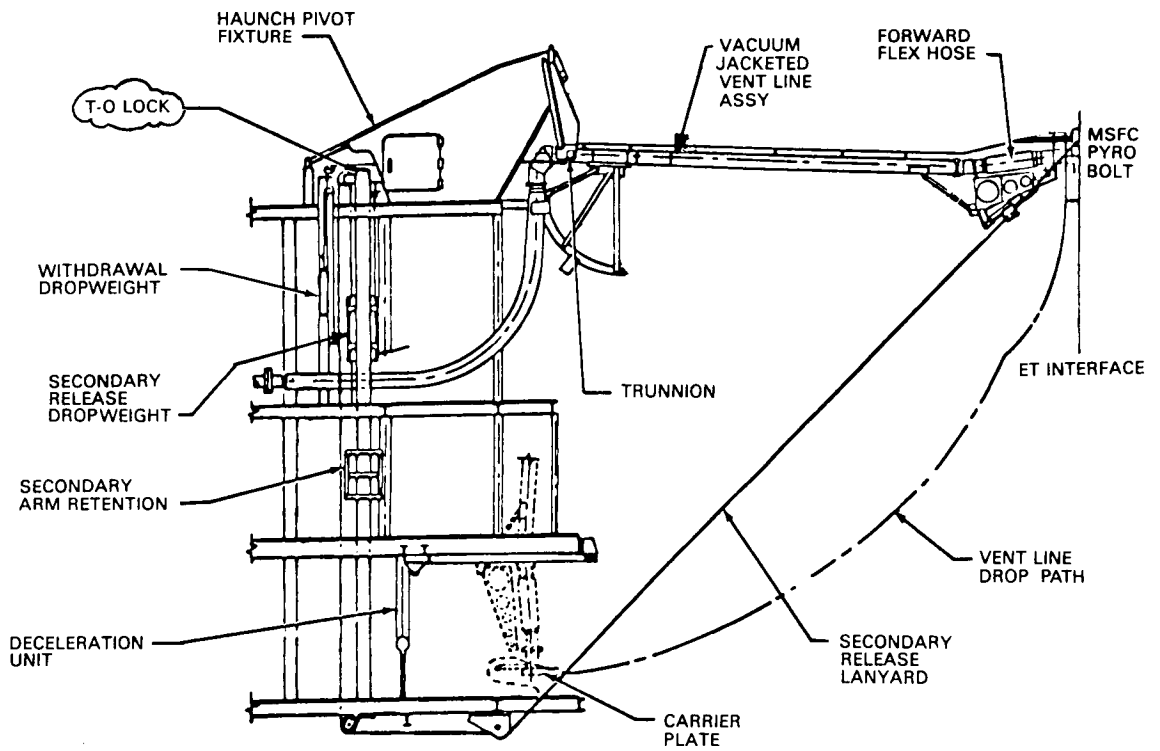


FIGURE 2: ET HYDROGEN VENT UMBILICAL SYSTEM

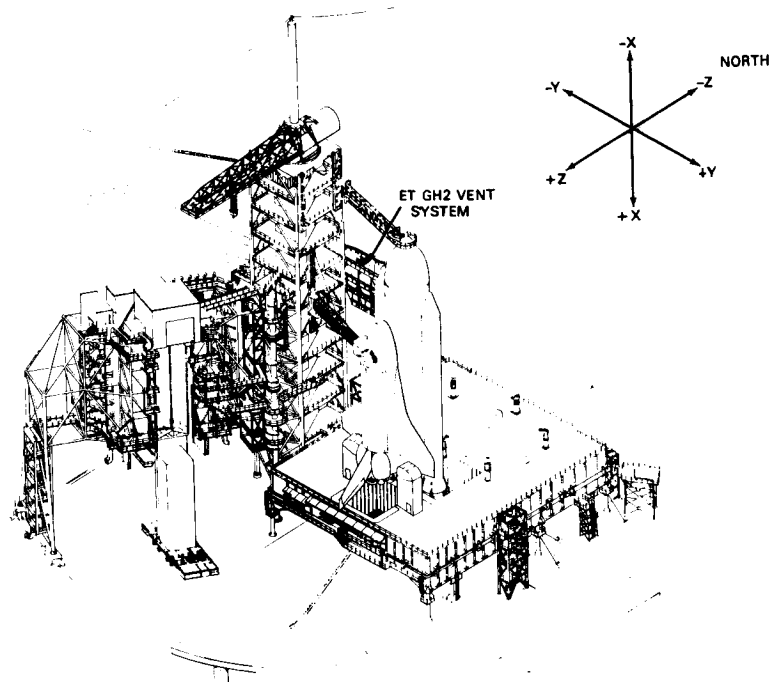


FIGURE 3: SPACE SHUTTLE VEHICLE LAUNCH PAD

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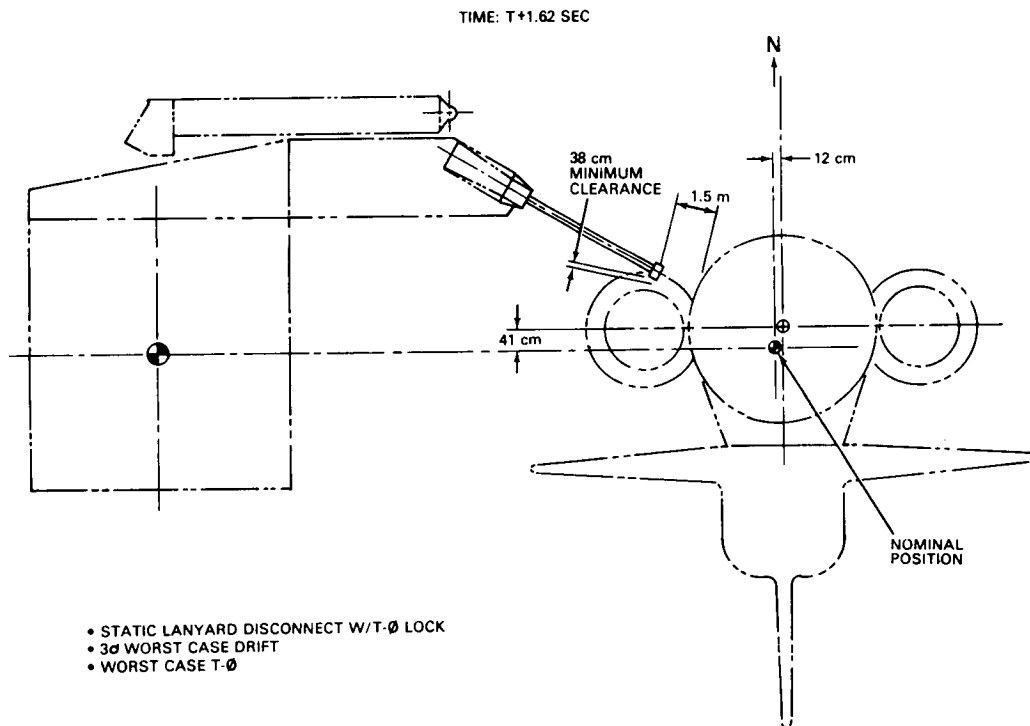


FIGURE 4: LIFTOFF - RETRACT CLEARANCE STUDY

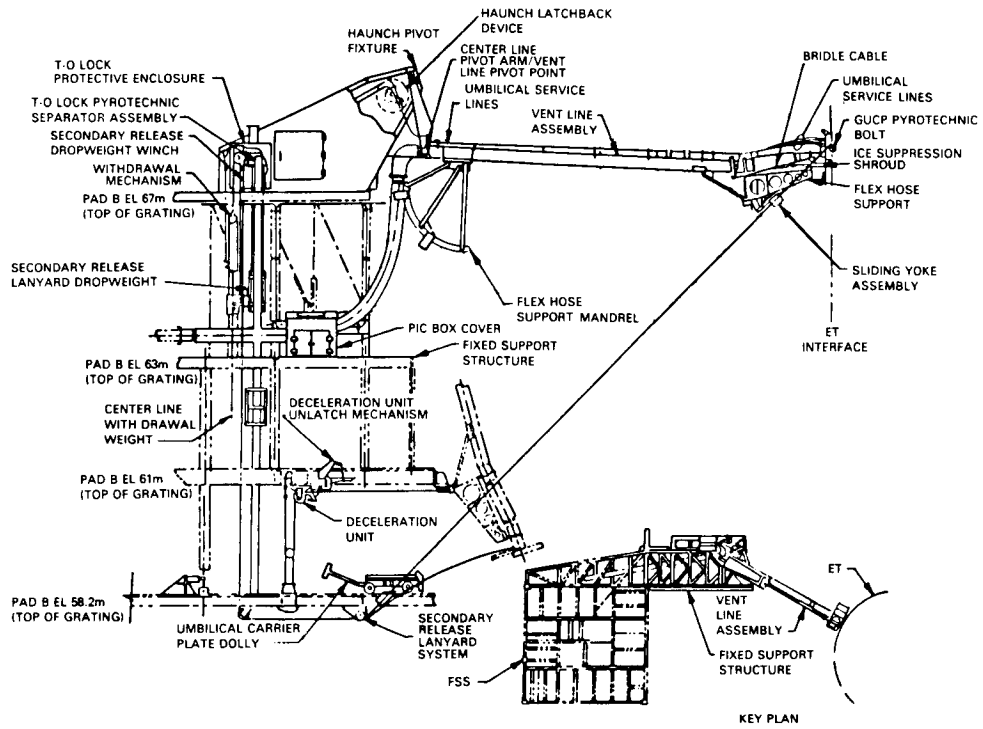


FIGURE 5: ET HYDROGEN VENT SYSTEM