



FedEx's Fire Suppression System



FedEx's Fire Suppression System



In September of 1996 a FedEx DC-10 had an in flight fire. While the crew was able to land and evacuate the aircraft, the aircraft hull and its entire contents were destroyed. The cause of the fire is unknown with the exception that it started in the freight being carried on the main deck.

This is the incident that started FedEx's research into main deck fire suppression.



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- FedEx ran multiple tests on Class A and Class B fires. It was determined that Class A fires were more difficult to suppress.
- Class C fires must have the power source removed before the fire can be extinguished. However, the cargo foam does wet the surrounding area and thereby reducing the possibility of the surrounding material catching fire.
- Class D fires were investigated



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In order to determine the most adverse fire scenario; multiple tests were conducted. FedEx has concluded that paper fires are more difficult to extinguish than pan fires (liquid fuel fires).



FedEx uses cardboard boxes (18"x 18"x 18") filled with 2.5 lbs. of shredded paper in our testing, an FAA standard.



The ULDs are filled 60 – 80 percent by volume. An AMJ (8'x 10'x 8' tall ULD) contains 112 boxes.





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To verify that oxygen starvation alone would not entirely suppress a fire; an AMJ was filled with a standard fire load and allowed to burn without an extinguishing agent.

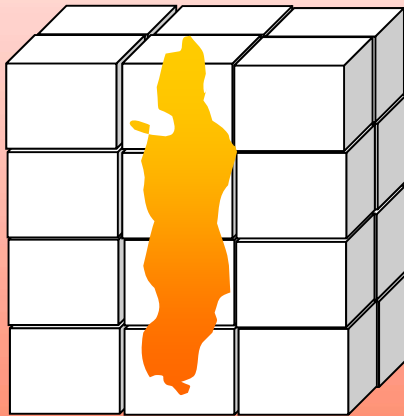


Suffocation alone was insufficient to contain the fire in a large ULD.

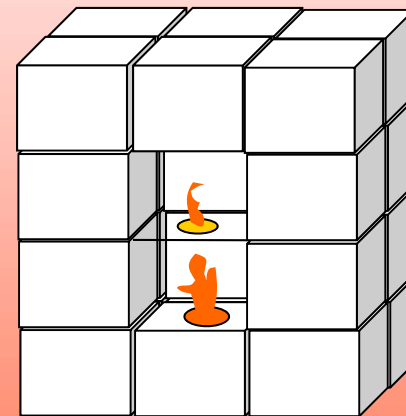


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Fires that start on the outer edge of the fire load burn hotter and spread faster than fires that start in the center of the load. Fires that were started in the center of the fire load burned between 30 minutes to two hours before the top of the container reached the set point. Fires that were started on the outer edge of the fire load took less than 10 minutes to reach the same set point on the top of the container.



Fire initiated on the outside of the fire load spreads quickly due to the lack of obstructions and an abundance of oxygen.



Fire initiated towards the center of the fire load has to burn through additional boxes in order to propagate.



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Issues influencing the design the Fire Suppression System

- Weight - Individual ULD vs. Entire compartment
- Cost - ULD contained vs. Aircraft mounted
- Effectiveness - Dry, Gas, Solid, Combination
- Personnel Interaction
 - Amount of flight crew interaction (automated vs. flight crew actuation)
 - Amount of ground crew interaction (hooking up hoses to each container)
- Method of loading cargo
 - Enclosed ULD (AMJ, SAA, etc.) vs. open ULD (pallet, "Cookie Sheet")

FedEx made the decision to have a Fire Suppression System (FSS) mounted in the aircraft as opposed to having a system in each individual container.



Several types of extinguishing agents were evaluated.

- Powder – Did extremely well on initial fire extinguishment, however did not prevent re-ignition.
- Gas – CO₂, Nitrogen, etc. Did well on the initial fire; however the ULDs have sufficient leakage that the gas did not stay in the container. Re-ignition was an issue.
- Intumescent coatings – Did well provided that the base material, the material that the ULD is made of, will withstand the heat until the coating intumescens. Polycarbonate did not. Vinyl did not. Also the coatings were found to be damaged during normal loading and unloading operations. The damage prevented the coatings from protecting the ULD.



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Several types of extinguishing agents were evaluated.

- Foam – Slow to inject into the container; however it remained for several hours slowly releasing the inert gas used to produce the foam. The foam also wets the surrounding cargo reducing the likely hood of the fire spreading.
- Gas used to produce foam.
 - Air – allows oxygen into the container
 - N₂ – added energy to extremely hot fires (N₂ breaking down)
 - Argon – single atom gas
 - Combination – added complexity system



Cargo Foam

- Starts cooling the container when injected.
- Wets the cargo it contacts reducing the spread of fire.
- Displaces oxygen.
- Traps toxic gases.
- Releases Argon when the foam breaks down.
- Is Biodegradable and Non-toxic.
- Ansul Proprietary

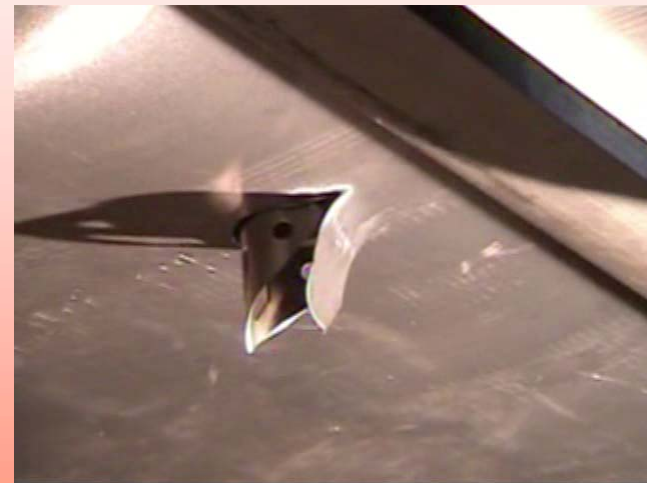


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Several methods of introducing the fire extinguishing agent to the inside of a ULD were considered. The two most promising methods were:



Hooking a hose to each individual container for the extinguishing agent to enter the container



Design a mechanism to puncture the top of the ULD and fill the container with extinguishing agent



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The puncture option was chosen because it would be less labor intensive during aircraft loading and unloading and involved fewer parts that could experience malfunctions which would eliminate fire protection from a given position.





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Various puncture tips were designed and evaluated.

Evaluations were performed to determine the least force required to puncture an AMJ. Other considerations included flow of the cargo foam through the tip and obstructions created by puncturing the AMJ (hanging chad)



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Various fire locations within the load



Various door curtain material



Various retention modifications

Multiple full scale, live fire tests using the cargo foam aerated with Argon as the extinguishing agent were performed.



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FedEx has developed a Fire Suppression System that will suppress a fire for four hours regardless if the freight is containerized or palletized



An aircraft based system for containerized freight.



A Fire Containment Cover for palletized freight.



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Active Fire Suppression System

- Mounted on board the aircraft
- For use with enclosed ULDs
- Automatic detection and activation
- No Ground or Flight Crew interaction required

Passive Fire Suppression System

- Individual Pallet Bags / Fire Containment Covers
- For use with open ULDs / Pallets
- Suppresses the fire by limiting the oxygen
- Installed prior to freight being loaded on aircraft
- No Flight Crew interaction



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Active Fire Suppression System



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View of the main deck of an MD-11 prior to the Fire Suppression System being installed



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Similar view of the main deck of an MD-11 after to the Fire Suppression System has been installed



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Installed Sensor Booms

Each boom has four thermal piles that detect heat (not smoke).

Each AMJ position has two sensor booms.

A minimum of two sensors must meet the set point to trigger the FSS.





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Installed Storage Tanks

Surfactant

FedEx Proprietary

Argon



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Installed penetrator modules

Penetrators can accommodate 96" or 79" tall ULDs

A single module can cover two ULD positions



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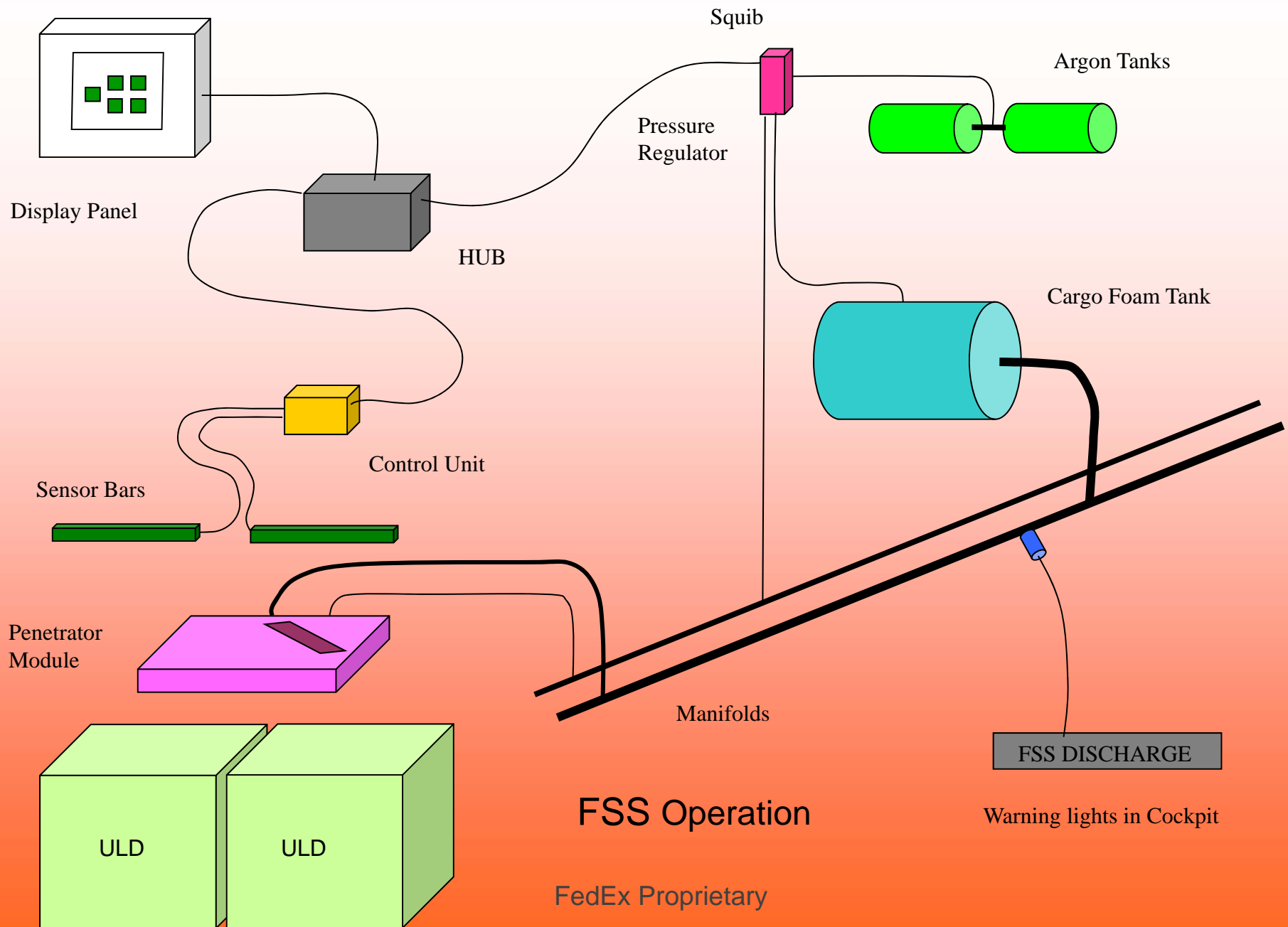


777 Installation

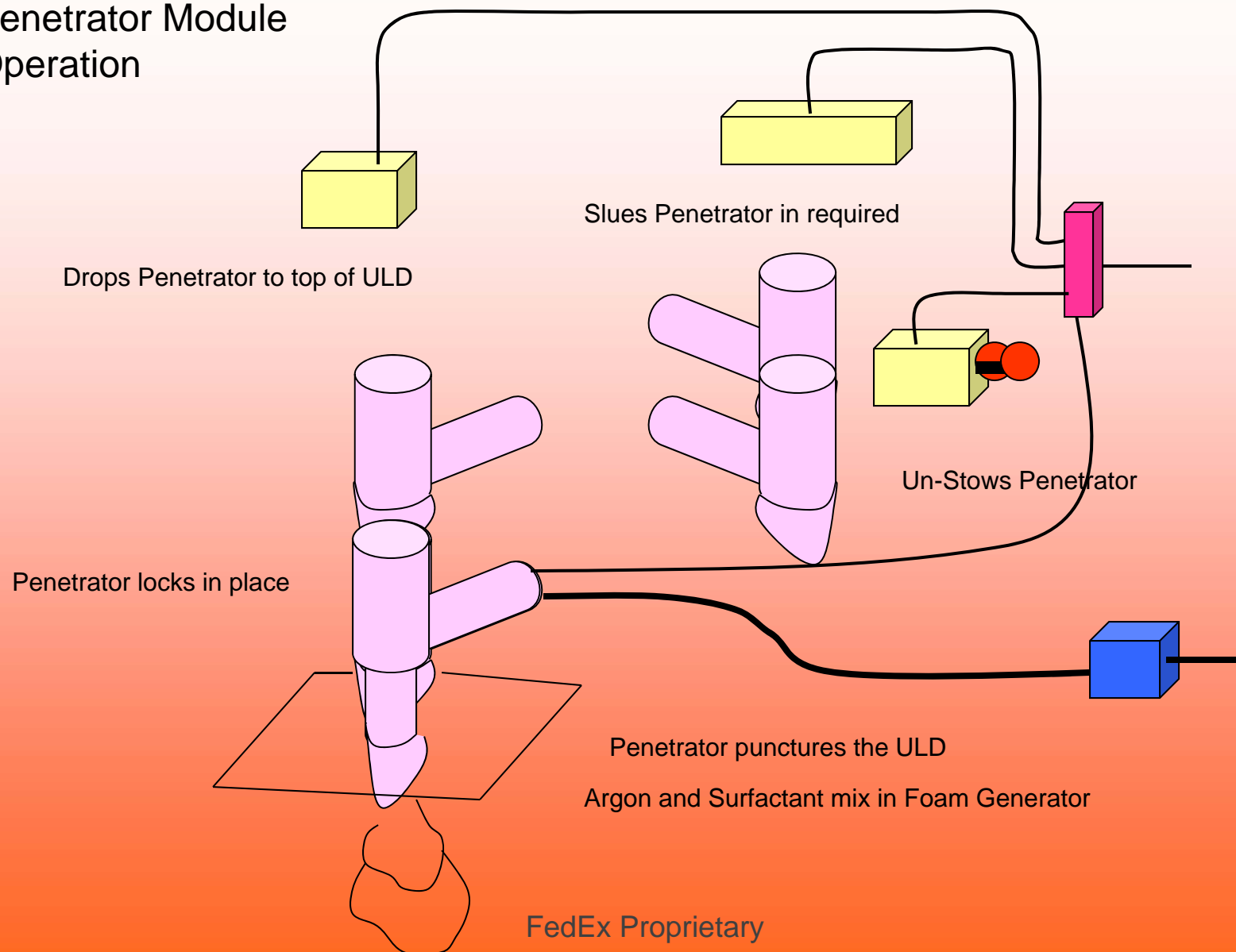
Same sensor booms

Storage tanks under
ceiling covers

Penetrator modules
can accommodate 96"
or 108" tall ULDs



Penetrator Module Operation





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Modification to AMJs for use with the FSS



Door Curtain

The ULD has to be made of a material that can withstand 1200°F for several minutes. Polycarbonates – melts below 400°F

Door Curtain

A poly vinyl curtain meets the FAR requirements but will not withstand a box fire. Therefore the door curtain has been modified to withstand 1500°F for two minutes and 1000°F for 10 minutes. Years of research and development has gone into the door curtain. Some of the same technology is used on the pallet bag.



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Modification to AMJs for use with the FSS



Side Flaps

Side Flaps

Side flaps are required to retain the cargo foam, without them the cargo foam would only fill the AMJ about four feet high.

The side flaps are painted red to indicate when they are open.

The door curtain can not be opened or closed when the side flaps closed.



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Modification to AMJs for use with the FSS



Door Bar Flap

The door bar flap seals against the threshold to reduce the cargo foam leakage

Raised Threshold

The threshold was raised to provide the door bar flap a surface to seal against

Door Bar Flap

Raised Threshold



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Fire Containment Covers (aka Pallet Bag)

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FedEx material testing revealed that current FAR material and vertical or horizontal burn testing is not sufficient to withstand a full scale pallet bag burn test where temperatures of over 1500 deg F (815 deg C) has been witnessed for greater than half an hour.

FedEx's initial testing of the FCC was for 4 hours; believed to be ample protection for the length for the longest duration over water for international flight. Testing time has now been increased to 6 hours.



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Loader (prototype) developed by FedEx Strategic Projects to aid in loading pallet bag onto pallet & dolly – not essential just conceptual





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Pallet bag in rolled-up position ready to load – total weight approximately 110 lbs. (including 45 lb. net). Can be loaded by forklift, loader or by hand.



Pallet bag unrolled
quick-zip net integral to pallet bag, no need to shrink wrap pallet load to protect from water and net does not get tangled!





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Ten minutes total time from rolled up bag placed on floor until the entire net was secure on load



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Pallet fire test load

Standard load is 114 18" square boxes with 2 ½ lbs shredded paper.



Pallet fire cover secured and ready to begin fire test





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Maximum internal temperature
1400°F (thermocouple).



Maximum external temperature of
cover 800°F (using IR camera).



Test stopped after predetermined
4 hours.

Pallet fire cover removed showing
fully engulfed cargo fire
underneath.



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Pallet fire cover fully removed – fire still burning after being doused with water –
at least 50% of freight intact





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Testing has been conducted to determine the effect of the cargo foam on fires containing Class D materials



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- Class D materials: Magnesium, Lithium and Sodium are the most prevalent.
- Class D fires do not react favorably when standard fire extinguishing agents are used.
- Halon is ineffective in most cases. It may actually make the fire flare up.
- Nitrogen (N_2) can be ineffective due to the Nitrogen bonds breaking thus releasing more energy.
- Argon gas does not add energy to the event.



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Shaved Magnesium was placed in a metal bowl, set on fire and the foam was allowed to flow over it.



- The fire was contained
- The foam did not extinguish the Magnesium
- All the Magnesium was consumed
- Flickering light was seen through the foam.
- pH of the foam above the container was 11



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Lithium was placed in a metal bowl, set on fire and the foam was allowed to flow over it.



- Gas released
- Sediments found in bottom of container
- pH of the liquid in the bottom of the container was 14





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Sodium is generally stored and shipped in kerosene, in well padded containers.





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Cubes of Sodium were placed in a metal bowl

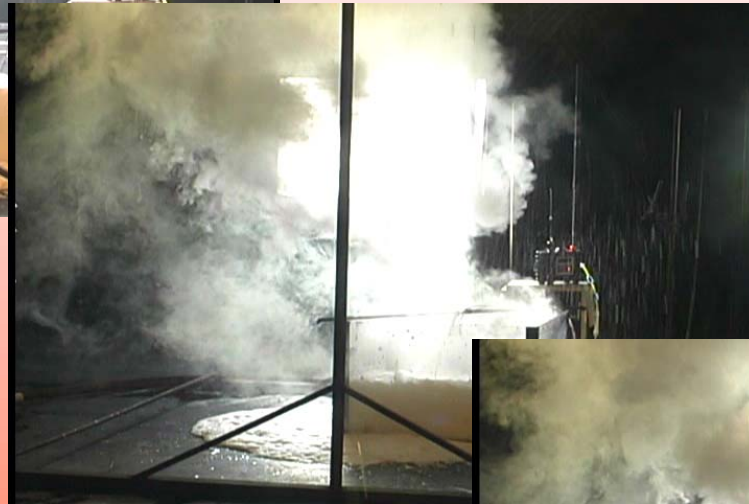
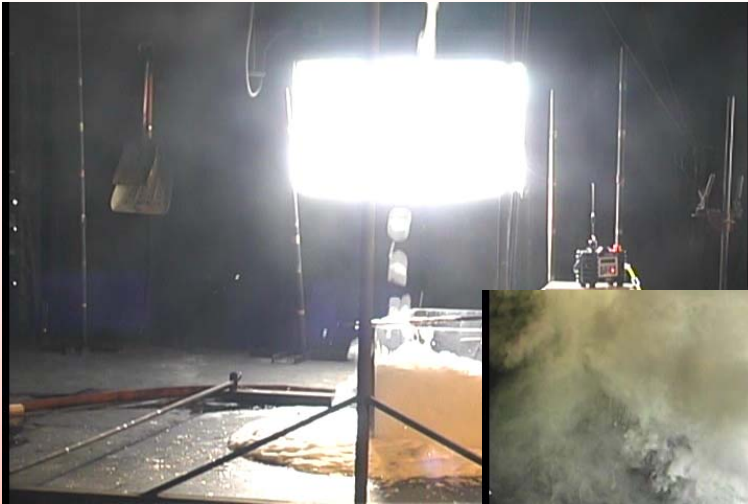
The Sodium was NOT set on fire.

As the Cargo Foam breaks down, Argon is released and the foam returns to a liquid form, comprising mainly of water.





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- Additional tests were performed.
- Increasing the foam depth or providing a path for the accumulating liquid to exit the area prevented the Sodium from exploding.

- Double the foam height gas released
no explosion
- Sodium placed on screen no gas observed
no explosion





One pound of Sodium in an AMJ

- Two layers of boxes were placed in an AMJ
- 450 grams of Sodium was placed a plastic bag.
- The plastic bag was placed in the box above the igniter box.
- The igniter was activated and set the load on fire.
- 55 gallons of cargo foam aerated with Argon was allowed to fill the AMJ. 55 gallons will be the standard amount carried aboard FedEx aircraft.
- Smoke continued to exit the AMJ for an hour.



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Igniter box with power cord
(orange) and thermocouple
(gray)

Box containing Sodium placed
on top of igniter box



Two layers of boxes
(18"x18"x18") with 2.5 pounds of
shredded paper each were
placed in ULD





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Fire was extinguished.

Foam was 18 to 24 inches above the top of the boxes when the container was opened after 4 hours

Only six boxes were breached by the fire.



The box containing the Sodium had been breached.

A one inch oval hole was found in the top sheet of the aluminum base plate below the box where the Sodium had been placed.



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Questions?