FuelShield™ – Alternate Fuel Tank Inerting That Also Protects Against Debris Impacts

By
N. Albert Moussa and Venkat Devarakonda
BlazeTech Corporation
24 Thorndike St. Cambridge, MA 02141
617-661-0700/ 617-661 9242(fax)
amoussa@blazetech.com

Presented at the
International Aircraft Fire and Cabin Safety Research Conf.
Atlantic City, NJ, 22-25 October 2001

BlazeTech

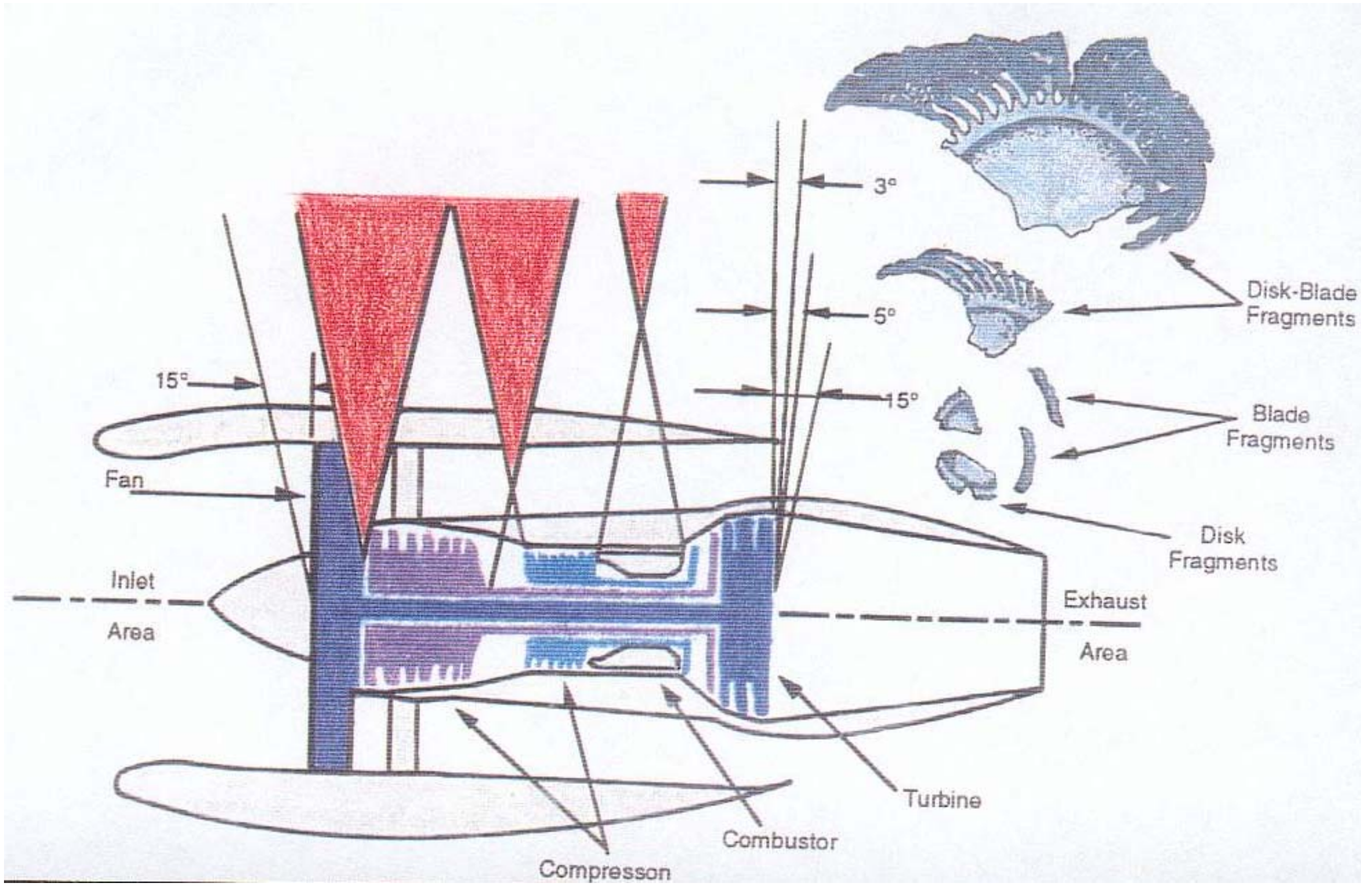
Introduction

- FAA concerned about uncontained engine failures
- Driven by accidents in Manchester, England, and in Sioux City, IA
- FAA Project at BlazeTech (1995): Effects of engine debris impacts on fuel tanks
- Two hazards of interest due to debris impacts
  - Fire/explosion in ullage
  - Hydrodynamic ram

Outline

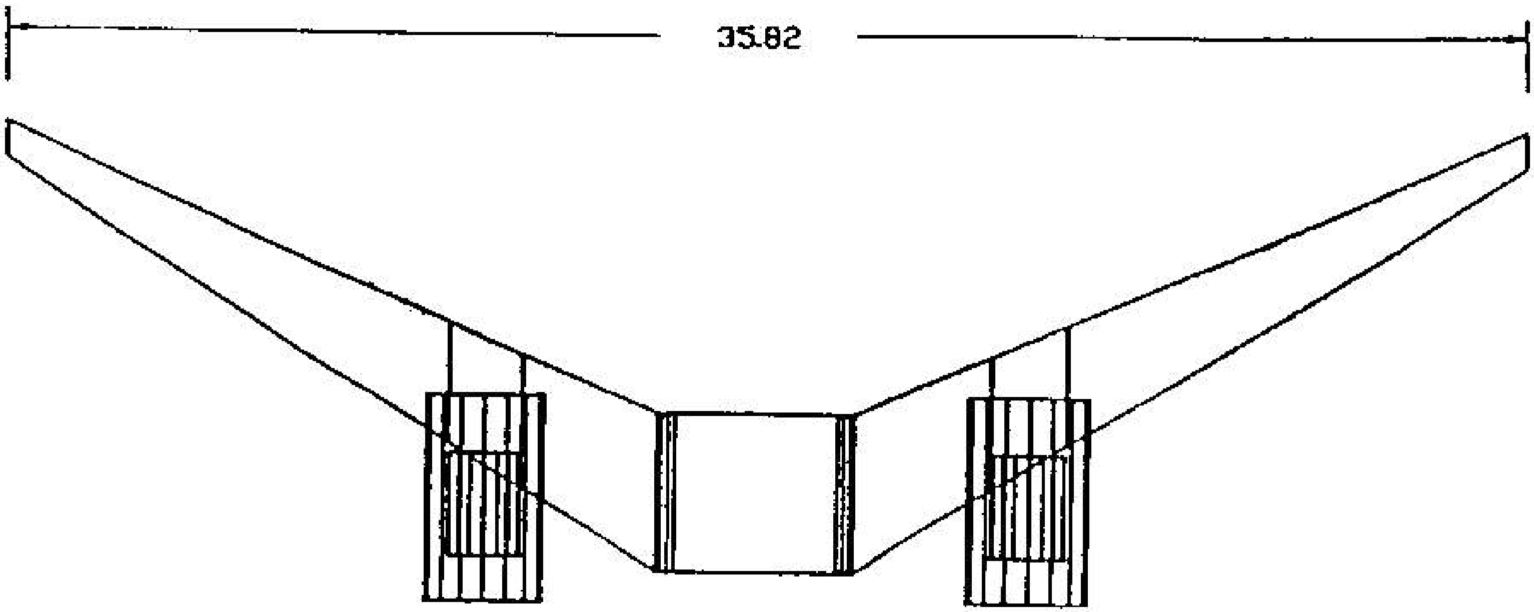
- Background on FAA study
- Summary of results on both hazards
- Related work funded by Air Force, Navy and BlazeTech
- FuelShield™:
  - Technology description
  - status of development

Debris from Uncontained Engine Failure



BlazeTech

Wing Mounted Engines

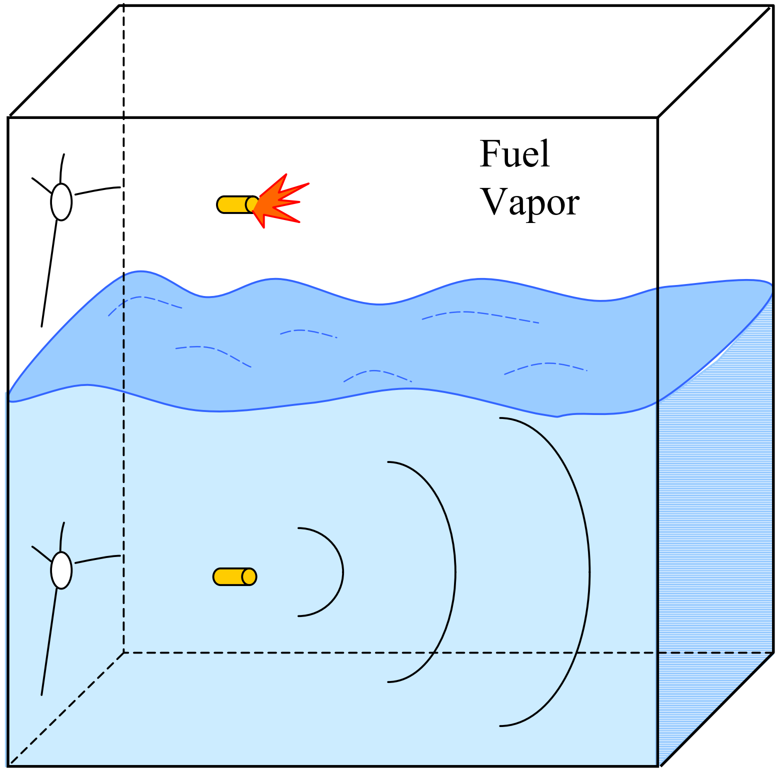


BlazeTech

Hazards in Fuel Tanks Impacted by Debris

1. Ullage Fire/Explosion

2. Hydrodynamic Ram



BlazeTech

Key Events in Ram

1. Debris enters tank
2. Pressure rise in tank due to motion of debris
3. Structural response and tank failure
4. Enlargement of penetration hole (more fuel leakage)
5. Fuel leak can produce fire and loss of aircraft

Ullage Fire/Explosion

- In FAA study, we characterized conditions leading to ignition
- Results were discounted until TWA 800 occurred
- Packaged the results into a model (BlazeTank) that predicts flammability, ignition and overpressure as functions of fuel properties, fuel tank design, flight profiles and impact conditions
- Presented it at last Fire and Cabin Safety Research Conference

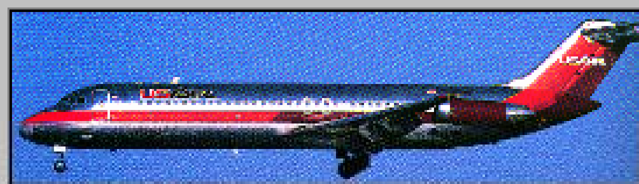
BlazeTech

Model for Ullage Fire/Explosion

About BlazeTank

BlazeTech **BlazeTank**

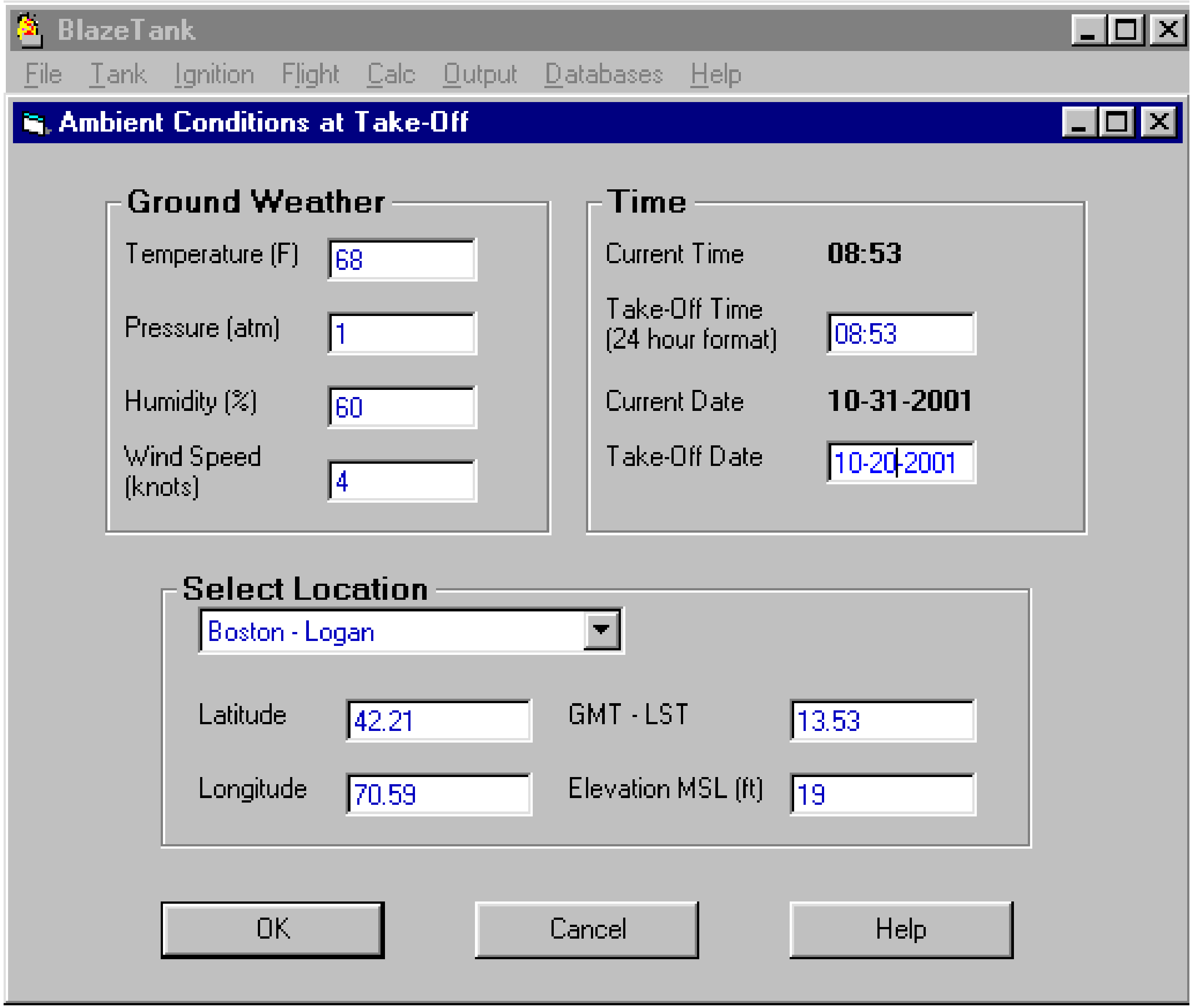
Version 1.0



OK

This software reflects BlazeTech's best judgment in light of the information available to it at the time of preparation. Any use of this software, or any reliance on or decision to be made based on it by any party (including third party, if any), are the responsibility of such party. BlazeTech accepts no responsibility for damages, if any, suffered by any party as a result of decisions made or actions taken based on this software.

BlazeTank Model (contd.)

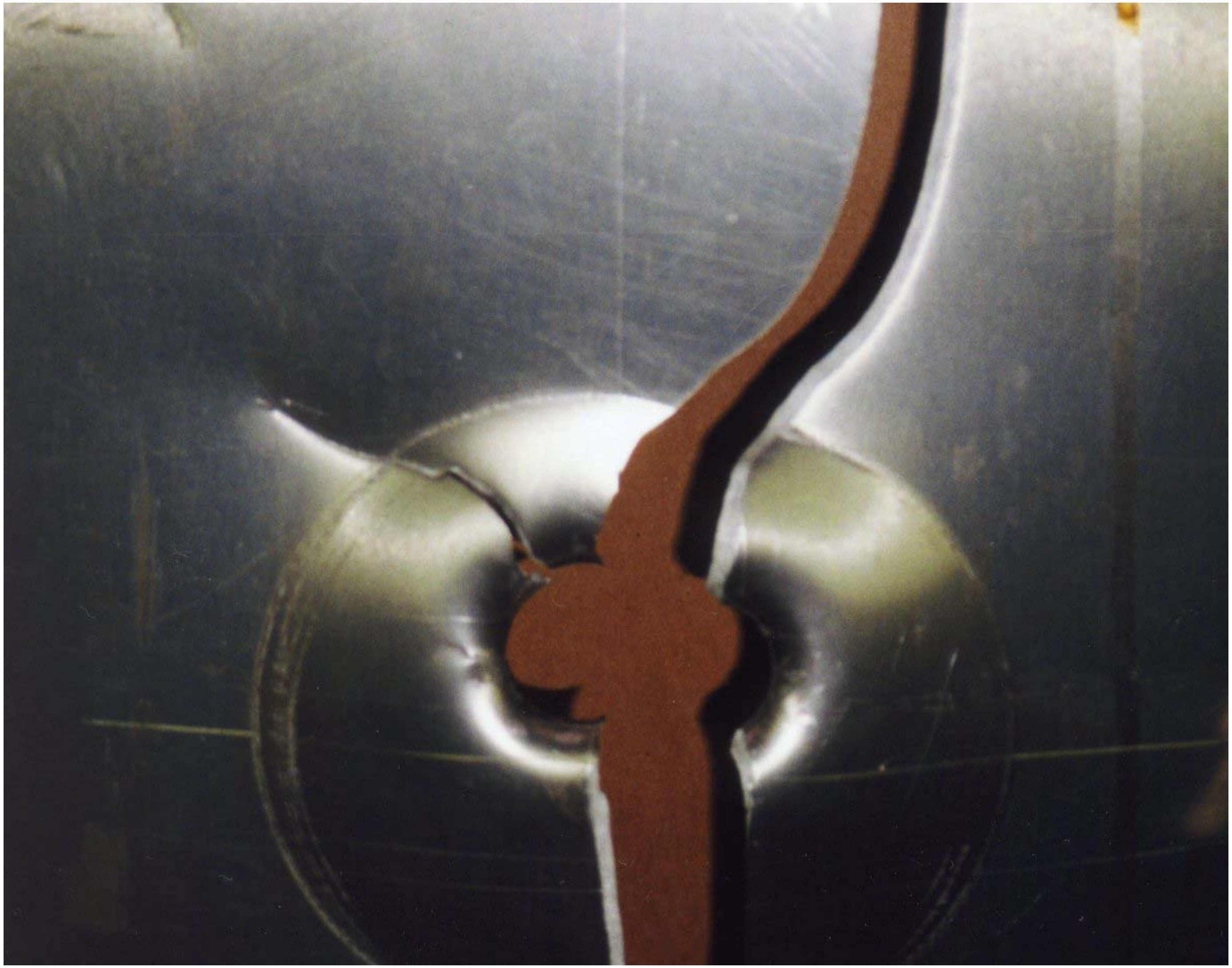


BlazeTech

Hydrodynamic Ram

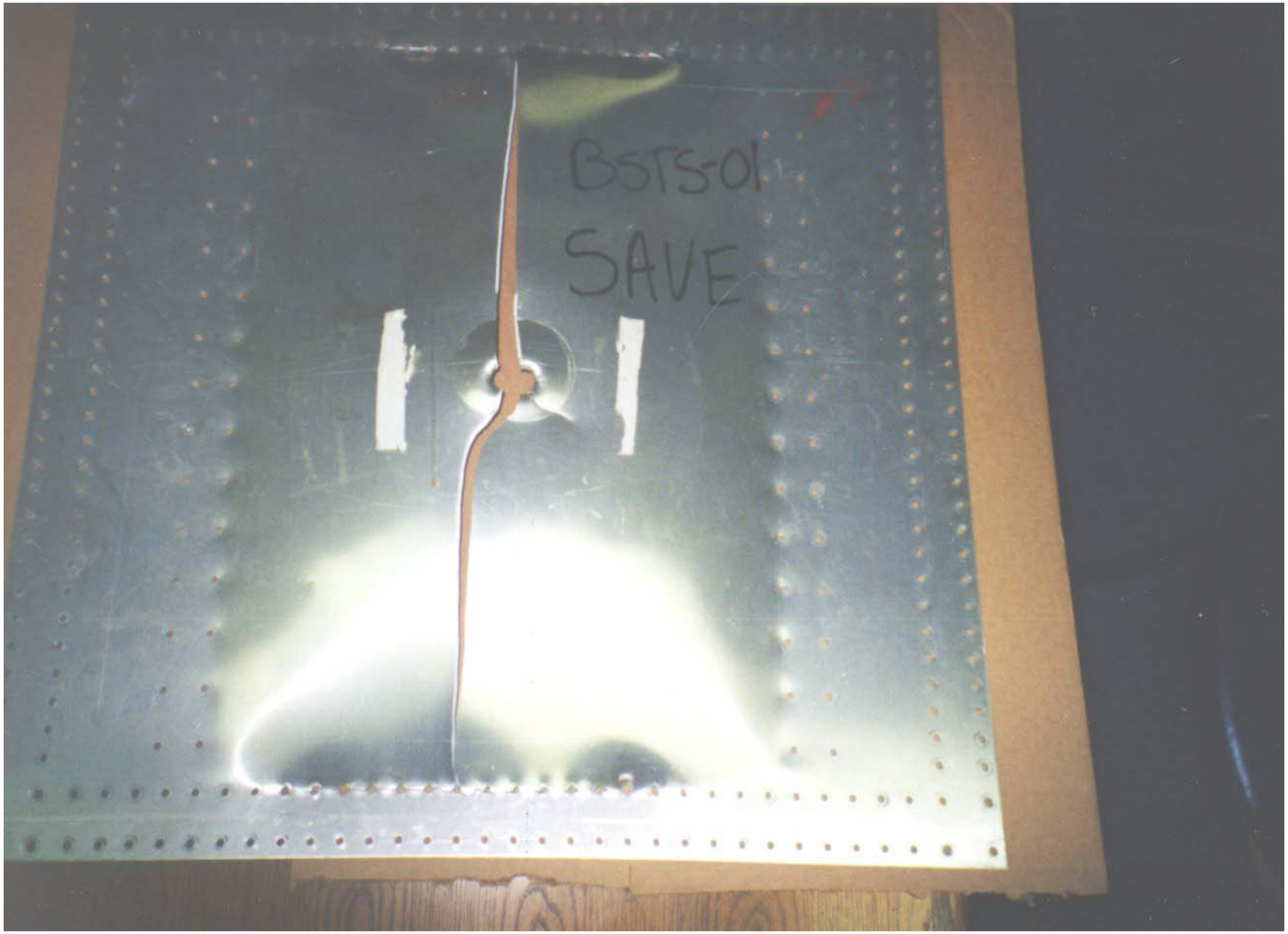
- In FAA study, we characterized conditions leading to ram
- Results completely ignored until Concorde accident
- Ram effect is well recognized in military aircraft
- How can you tell a ram effect?
  - Examine damage to tank wall
  - Tank tears out even though it is punched in
  - Tear in wall is much larger than punched hole

Bullet Hole and Circumferential Cracks



BlazeTech

Overview of Front Panel Deformation & Rupture



BlazeTech

Tank Wall Damage Due to Hydrodynamic Ram: Test Data

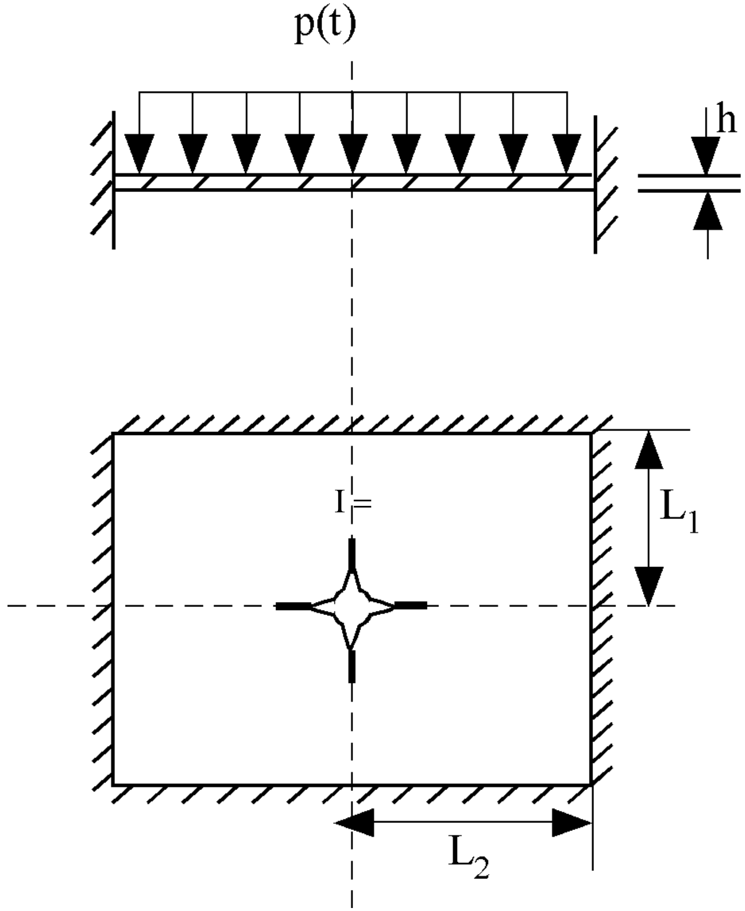
Source	Impulse (Psi-s)	Final Deflection (in)	Crack Length (in)	Crack Area (in^2)	$\frac{A_{crack}}{A_{projectile}}$	$\frac{A_{crack}}{A_{plate}}$
Navy[1]	0.097	3.15	>4.9	12.6	64	0.133
Air Force[2]	0.071	3.74	>15.8	18.6	29	0.027
	0.128	5.31	>15.8	37.2	54	0.054
	0.017	Minimal	Perforation only	N/A	1	0

[1]Panel: Al 7075-T6, Curved, 9.84x9.65x0.0787 (in)

[2]Panel: Al 2024-T3, Flat, 31.5x21.7x0.157 (in)

BlazeTech

TankCrack: Model of Structural Response and Failure



Assumptions:

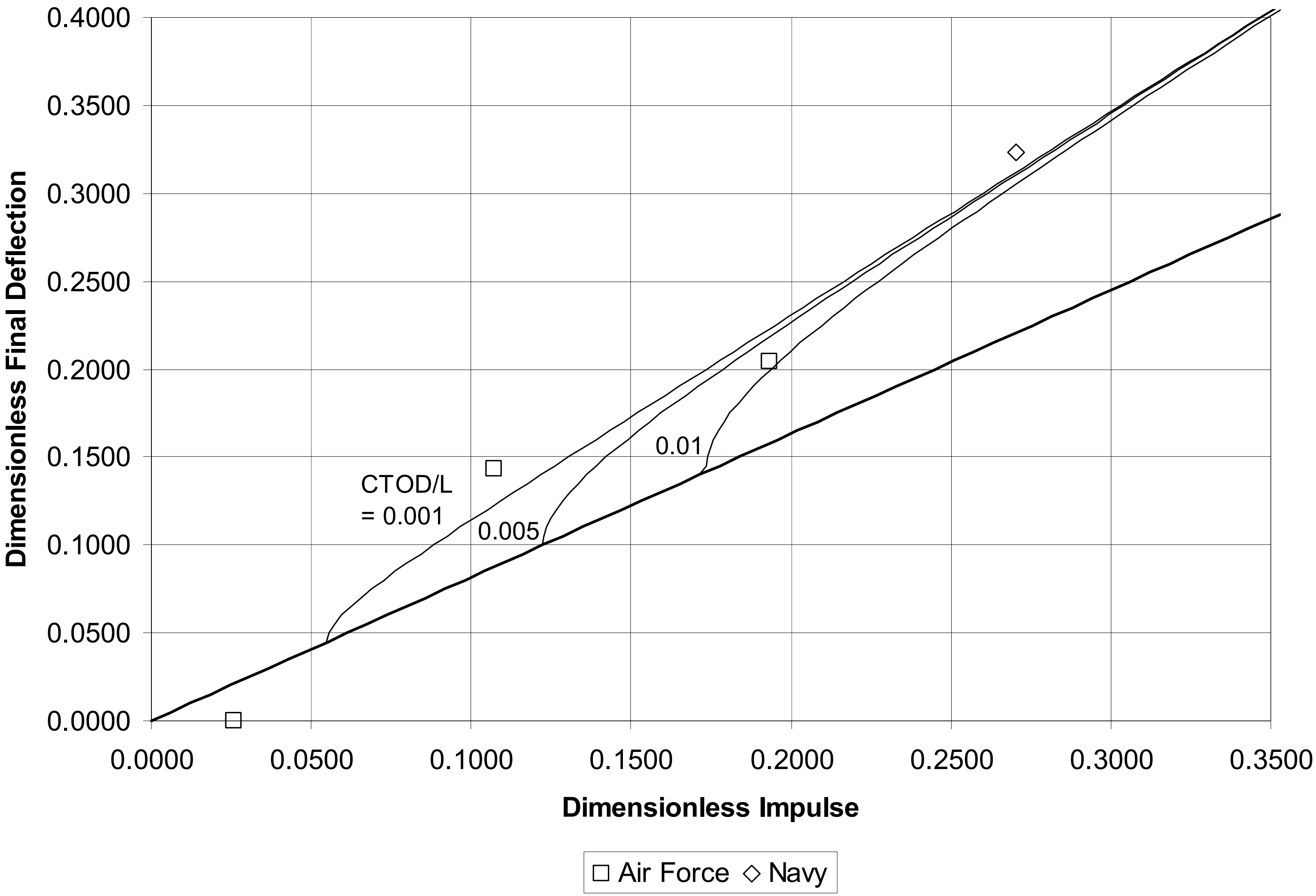
- Thin, clamped, rectangular plate
- Small diameter hole at the center with a distribution of starter cracks
- Impulsive loading, $I = \int p(t)dt$
- Plastic deformation and failure

BlazeTech

Plate Failure Criterion

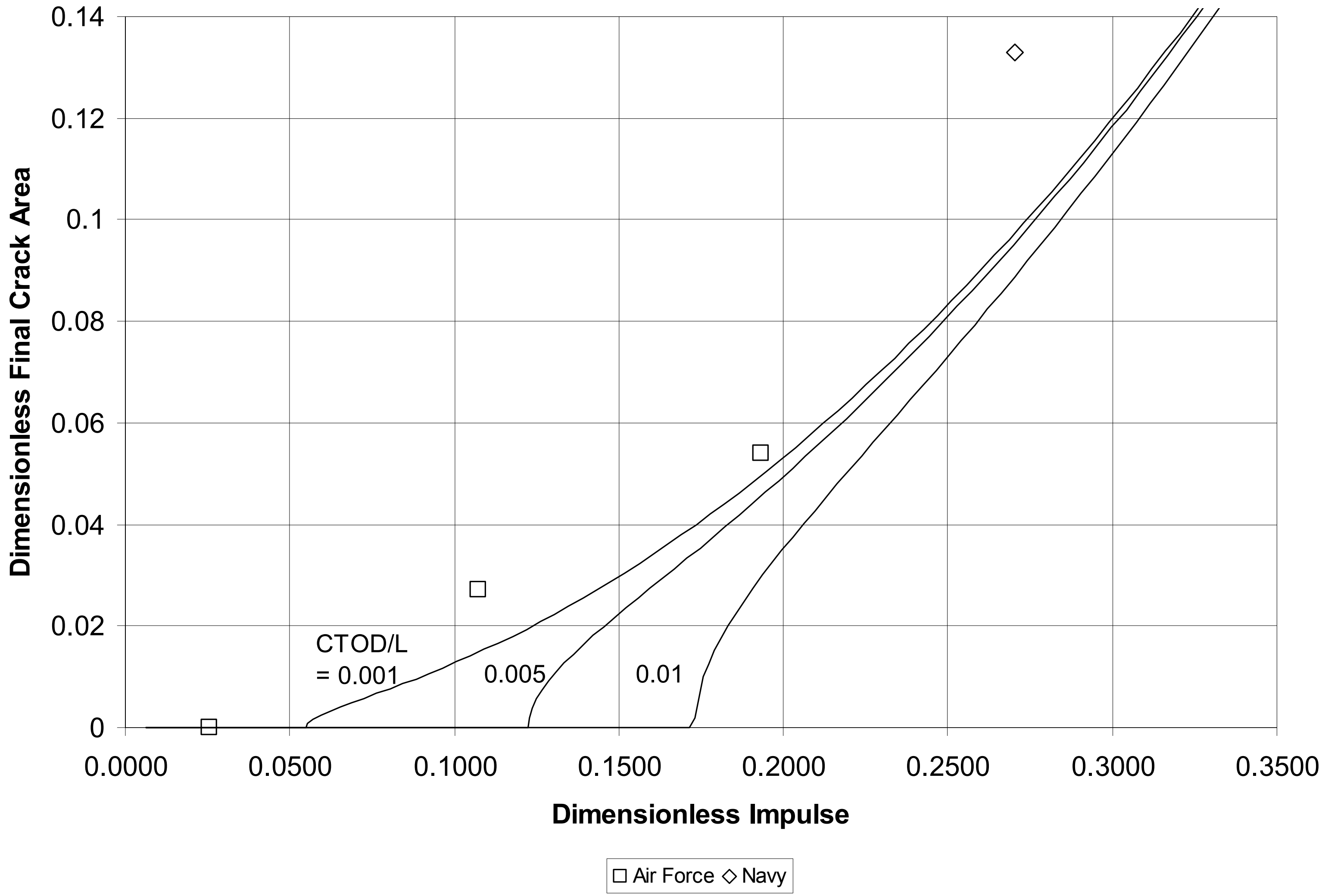
- Plate deflection grows due to applied impulse.
- Crack will grow when the Crack Tip Opening Displacement (CTOD) reaches a critical value.
- The critical value of the CTOD is a material property; a value of ~ 10 mils matched the data well.

Final Deflection at Plate Center: Predictions vs. Tests



BlazeTech

Crack Area: Model Predictions vs. Test Data

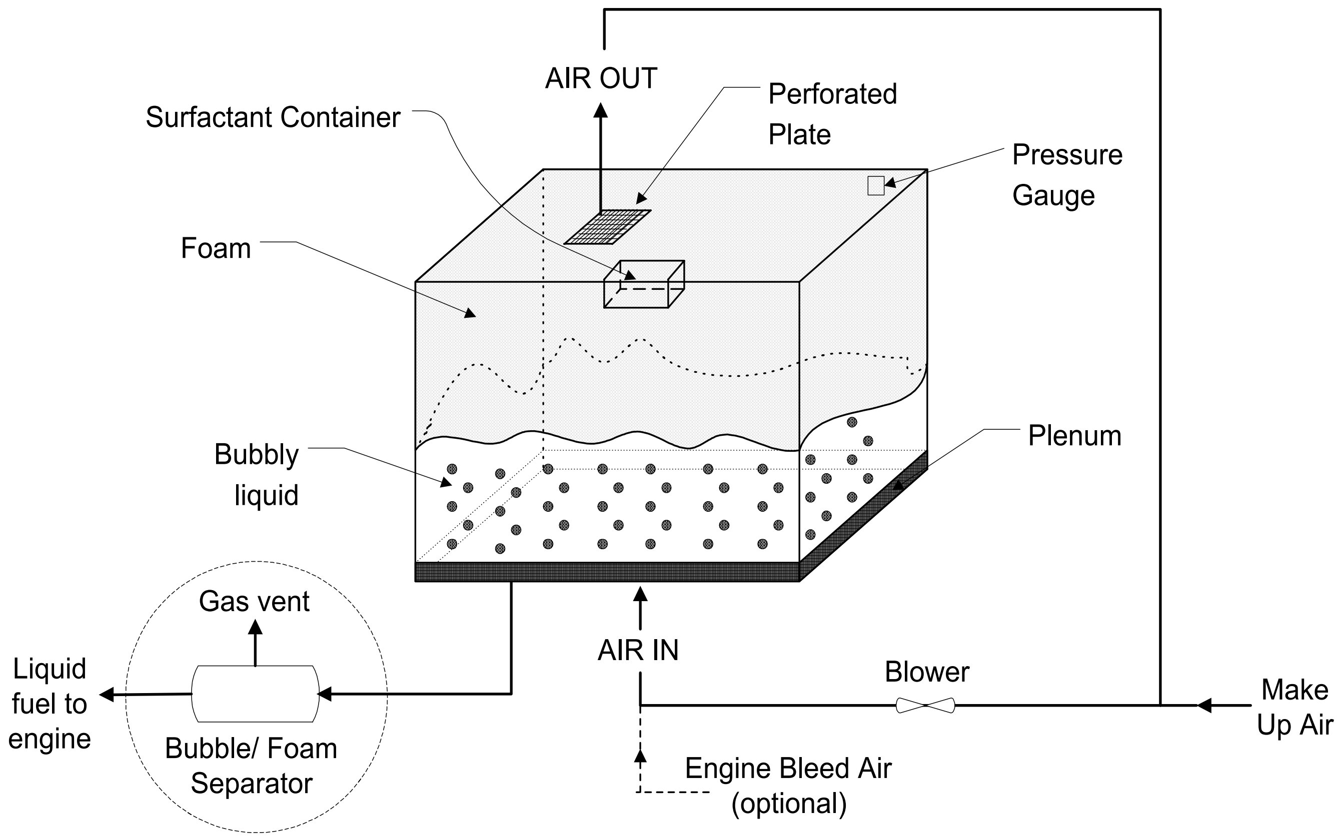


BlazeTech

FuelShield^{TM}

- Mechanical/chemical treatment of fuel to protect fuel tanks against both ullage fire/explosion and hydrodynamic ram
- Technology under development for military aircraft
- Is it useful to civilian aircraft as an alternate to inerting, particularly in view of attacks on Sep. 11?

FuelShield™: Schematic of Overall Design

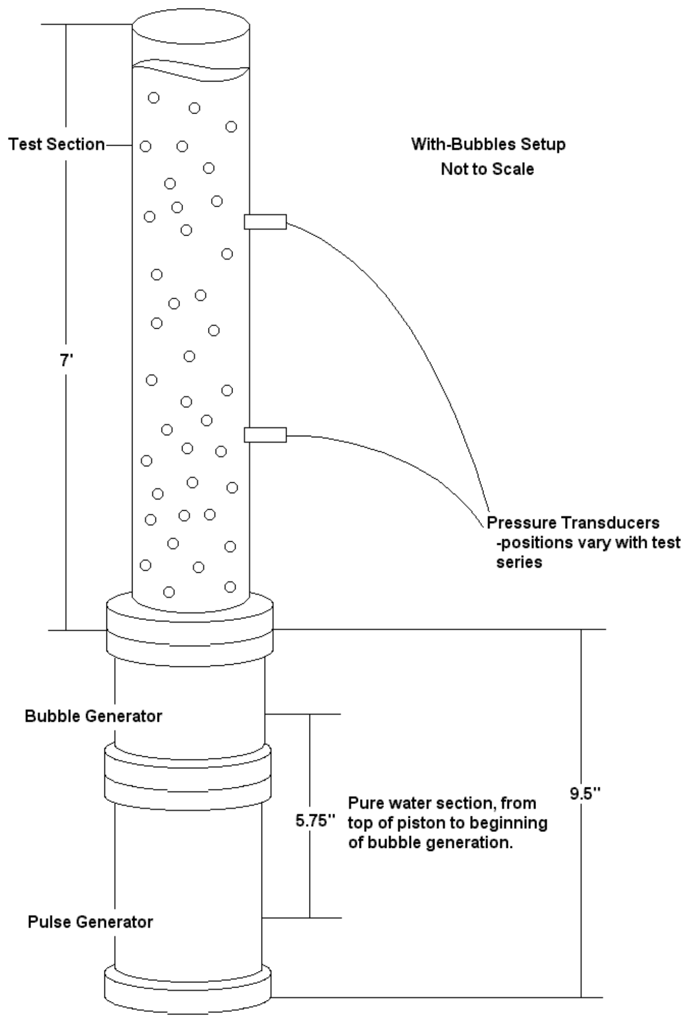


BlazeTech

Technology Description

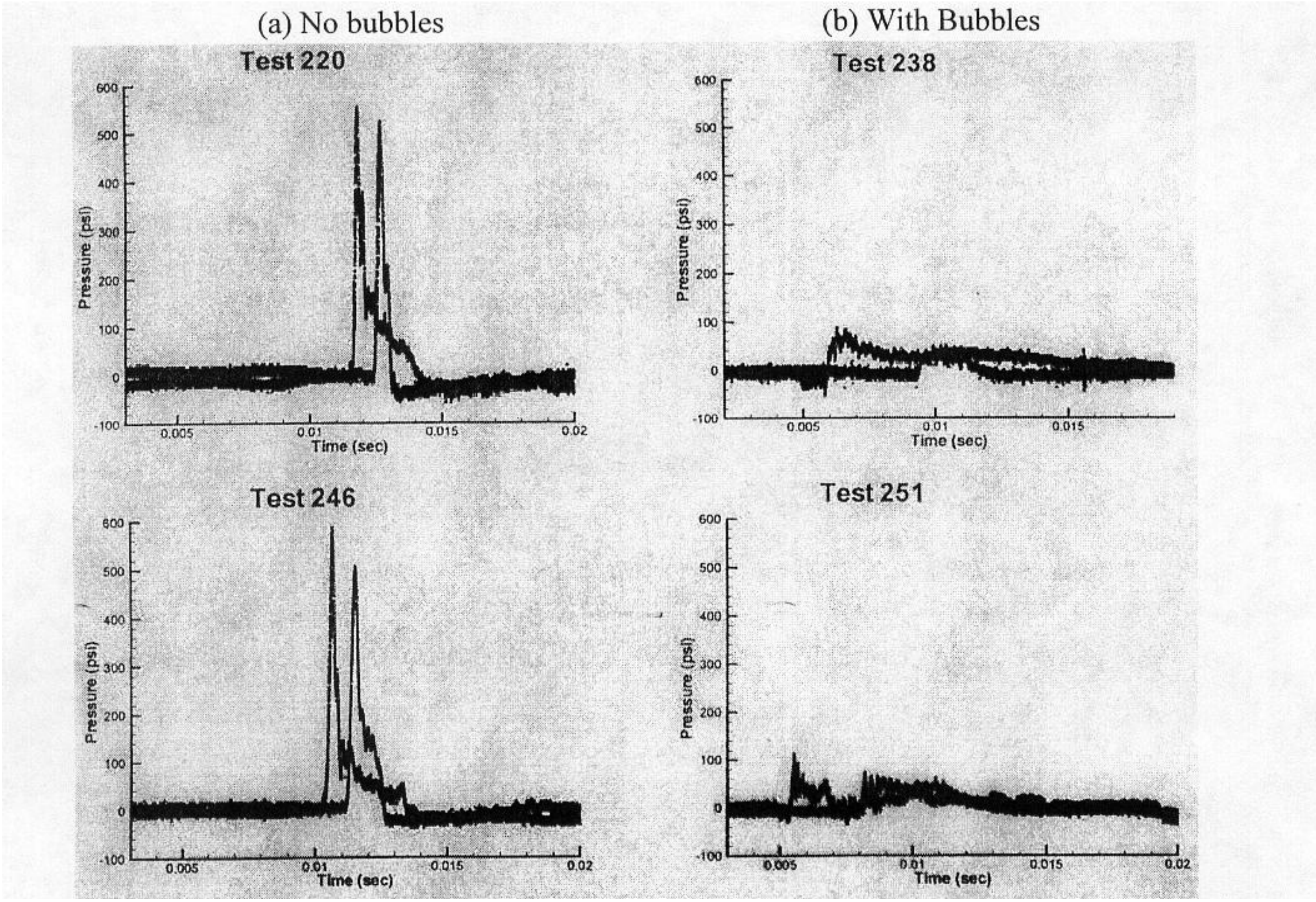
- Bubbles in liquid mitigate pressure wave from ram
- Foam in ullage mitigates ignition and flame spread
- Status of Development
  - Successful lab scale tests at BlazeTech
  - Successful preliminary gunfire tests at Navy's China Lake facility
  - Two patents pending

Bubbly Liquid Shock Tube



BlazeTech

Representative Attenuation of Pressure Pulses



BlazeTech

Fuel Foam Results

- Tested around 30 surfactants: two showed good foaming potential in a range of hydrocarbon fuels
- Organic based surfactants and < 1% needed – burn with minimum impact on combustion or emission
- Foam cell characteristics:
  - Expansion ratios > 20
  - Small foam cell size (1-5 mm)
  - Extremely stable and reproducible foam
- Bubbling action sufficient to initiate foaming
- No corrosion (iron)

BlazeTech

Future Work

- Full scale gunfire tests, planned in 2002 at the Air Force
- Examine practical considerations:
  - Effect on engine parts
  - Operational and environmental effects of surfactant
  - Foam activation and flight profile
  - Mode and time of surfactant addition
  - Applicability to various airplanes and fuel tanks
- Seek partners for additional development and commercialization

Summary

- Hydrodynamic ram can be a hazard even on commercial airplanes
- Presented a model (TankCrack) of hole enlargement via plate cracking under hydrodynamic ram that agrees well with the available data
- Presented a protection method (FuelShield^{TM}) against both ram and ullage fire/explosion.

BlazeTech