Studying the Accumulation of Water Ice on Fuel Lines and System Components

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Outline

- Background
- Preliminary Work
- Improved Facility
- Planned Testing
- Status

Background

- FAA/EASA seeking to study fuel system icing in the wake of two incidents, one of which was a CAT 1 mishap (0 Fatalities)
  - BA 777 landed short of runway at Heathrow due to engines not responding to commanded thrust
  - Delta flight had “single engine roll back” with many of the same conditions observed
- Investigation Focused on water ice accumulation in fuel lines at low fuel flow rates (cruise and descent) that was dislodged when high thrust was commanded
  - Duplicating the precise chain of events during lab work has been problematic
  - Modifications to FOHE configuration on AC type proposed fix

Background (continued)

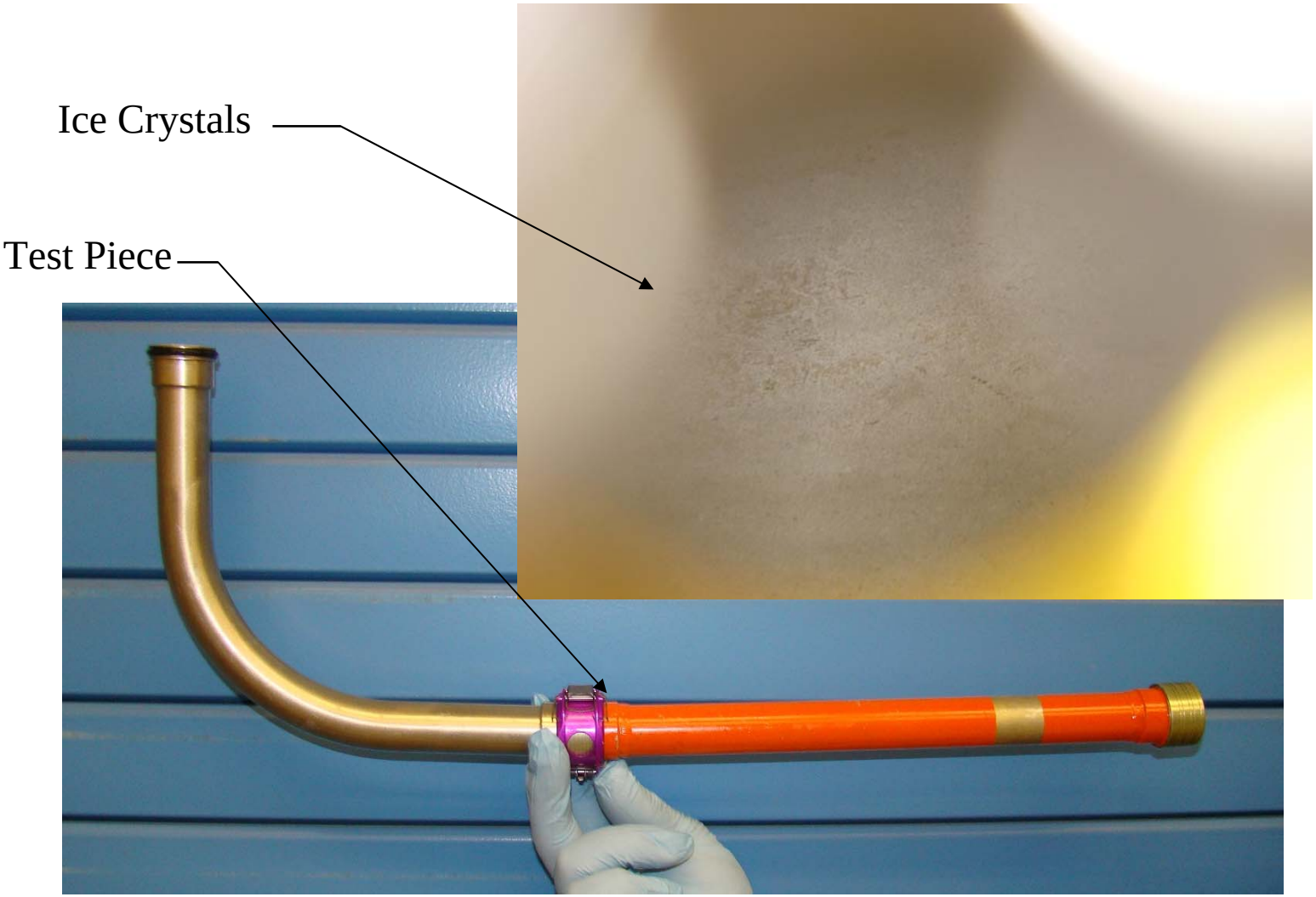
- IAB Investigation has recommended FAA/EASA study certain aspects of fuel water ice freezing
  - UNKG-2009-032: “It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency jointly conduct research into ice accumulation and subsequent release mechanisms within aircraft and engine fuel systems” (FAA rec 09.049 per Mike Dostert)

Photo of BA 777 Heathrow Accident Site

Preliminary Testing

- Used a simple test setup to examine the ability to accumulate ice on a single 12-inch long aluminum tube
  - Performed tests with fuel that was stored in a reservoir and saturated with water (~80 PPM) at 80 deg F and then reduced temperature to 10 deg F
  - When the test article was exposed to fuel at low flow rates (< 2 gals/minute), trace ice accumulated on the wall of the tube
  - Attempts to add more water to fuel (to create more ice) resulted in ice forming on the walls/bottom of the reservoir tank
- Tried to add water through a heated line to the 10 deg F fuel just up stream of test article during testing to get greater quantities of water ice onto fuel line
  - Water froze at line opening blocking flow

Photo of Accumulated Ice Crystals on Tube Wall

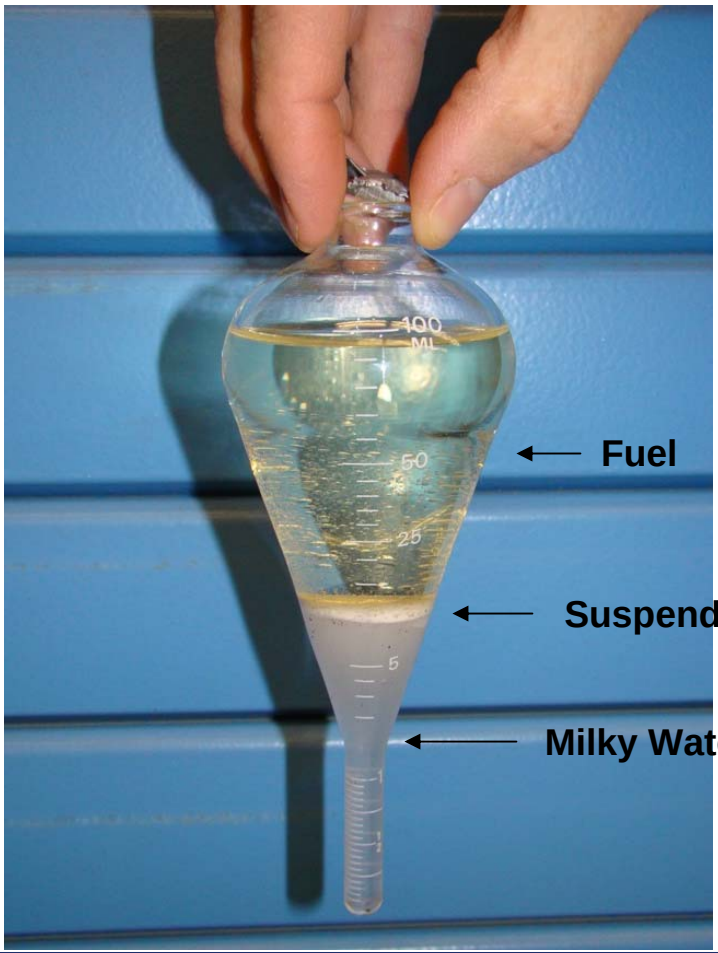


Preliminary Testing (continued)

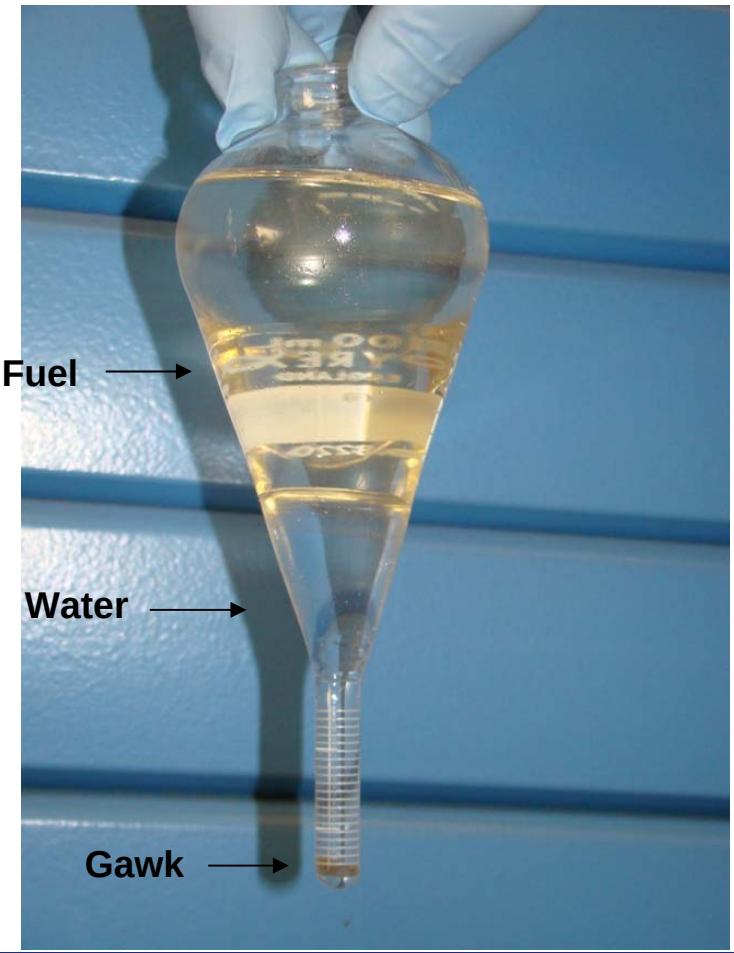
- Preliminary tests with fuel from the Tech Center JP-8 supply allowed for no ice formation in test piece
  - Found facility fuel delivered with FSII added
  - Used procedure to remove FSII from fuel by adding water, waiting, and then sumping tank
  - FSII has a high affinity for water and therefore is susceptible to migration from fuel given large quantities of water
  - Verified procedure works with lab tests of fuel samples
- Observing fuel with and without FSII added illustrates the behavior differences of fuel with FSII
  - Water with FSII maintains a milky appearance and demonstrates a high surface tension

Photo of Tank Fuel Sump Samples With and Without FSII

With FSII



Without FSII (Typical)



Facility Improvements

- Observations from preliminary testing casts doubts on the ability to add water to the experiment as it takes place
  - Completely contrived method / no basis in reality
  - Previous tests have been performed by maintaining the frozen water in the fuel supply
  - Visited the ice exposure test facility at Parker Aerospace and discussed methods with the resident ice testing guru
- Developed a new facility to perform more elaborate experiments
  - Created a reservoir with mixing capability to prevent water ice from adhering to surfaces
  - Created sealed, instrumented environment tank with some independent fuel temperature control

Block Diagram of Fuel Water Icing Test Facility

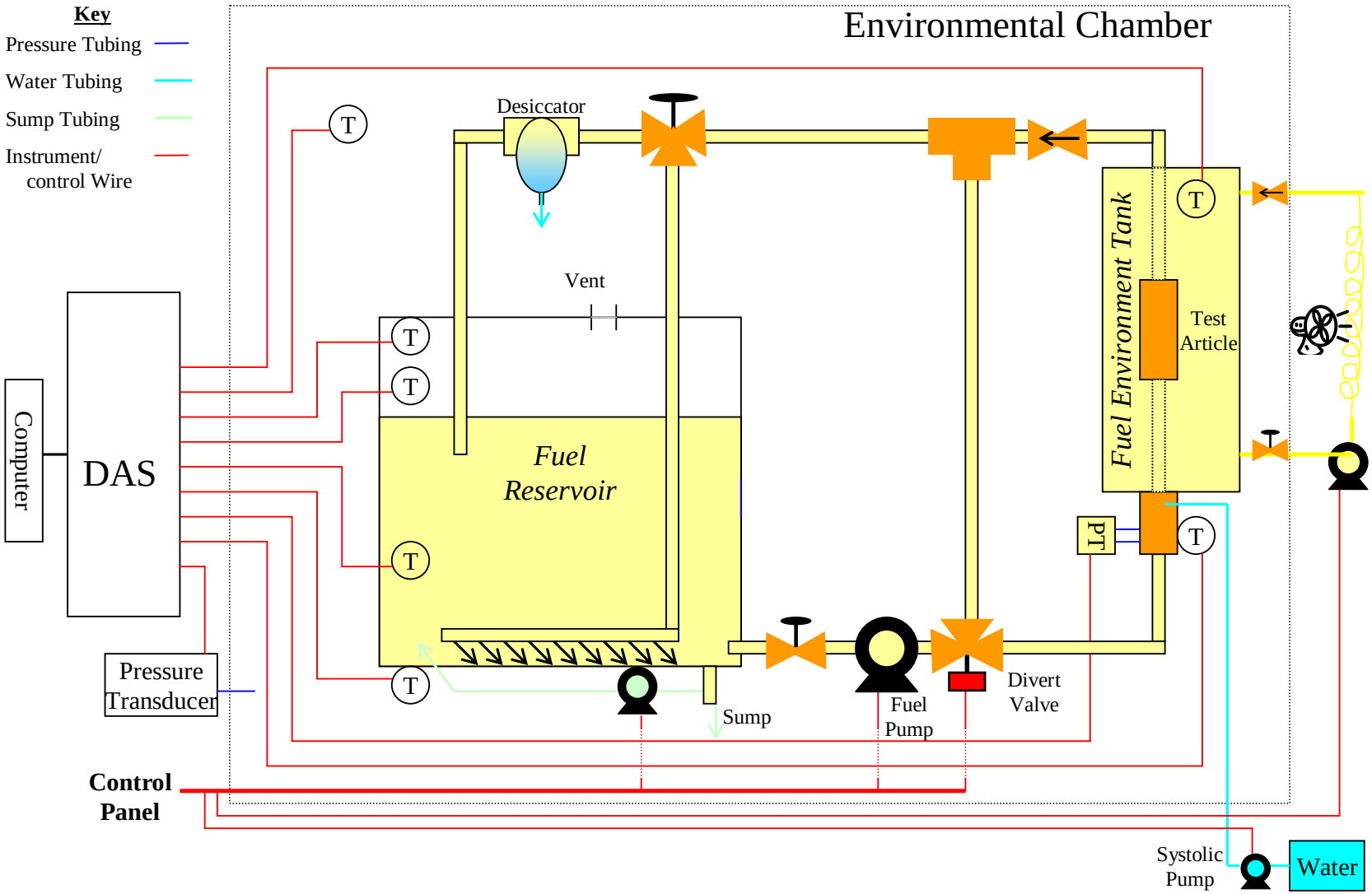
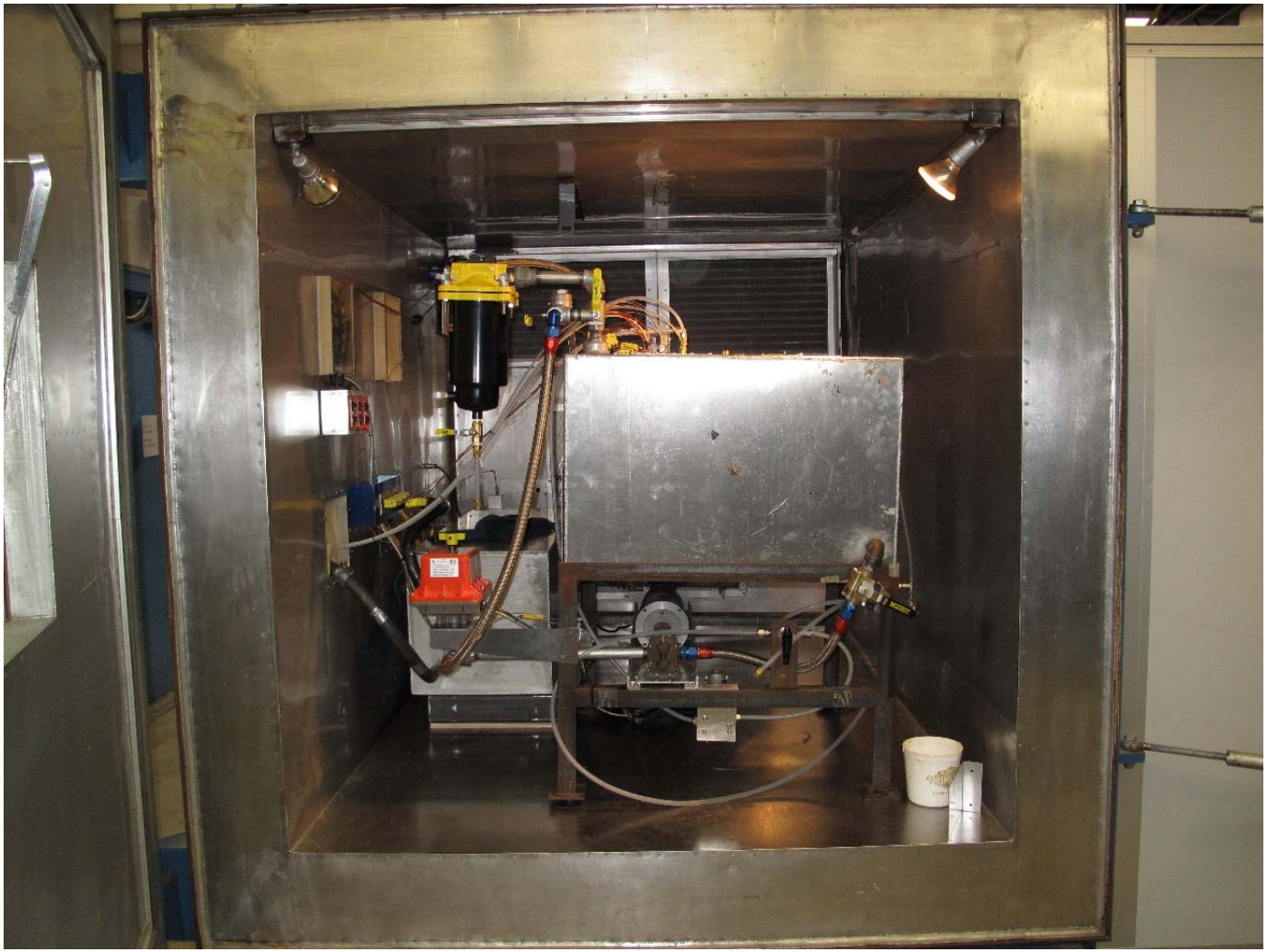
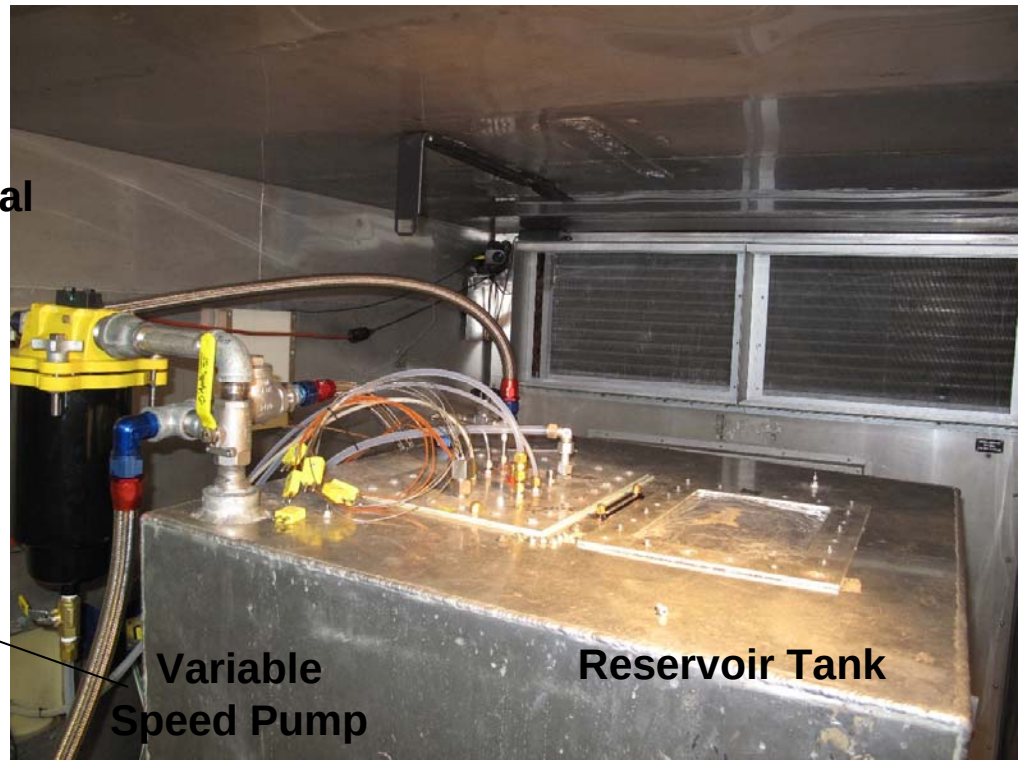


Photo of Fuel Water Icing Experimental Setup in Environmental Chamber



Photos of Fuel Water Icing Experiment Components



Planned Testing

- Do tests to accumulate ice on the walls of an aluminum tube under a variety of conditions
  - Focus on flow rates and water saturation levels that accumulate ice at the prevalent icing temperature (10 deg F) and try and correlate those to the amount of ice accumulated
  - Plan to vary the temperature of environment and fuel to try and accumulate different types of ice (hard and clear vs. slushy)
  - Challenge is to be able to add and remove water from fuel so as to know the water levels of each experiment
- Modify facility and do tests to examine the conditions under which accumulated ice could be shed from tubing and captured downstream
  - These conditions represent the truly hazardous ones

Status

- All parts for the new setup have been received and installed.
- Leak check of entire system is complete
- Presently seeking the capability to have separate fuel handling capability for Jet A1 deliveries
  - Removing FSII from JP-8 each fuel load is cumbersome
  - Purchase of EPA approved fuel tank is pending
- Validation of entire facility capabilities has begun
  - Need to make sure ice will stay suspended in experiment until it reaches the test article and test water levels are predictable
  - Recalibration of fuel pump flow rate necessary
- Testing to start after above is complete (June ’10)