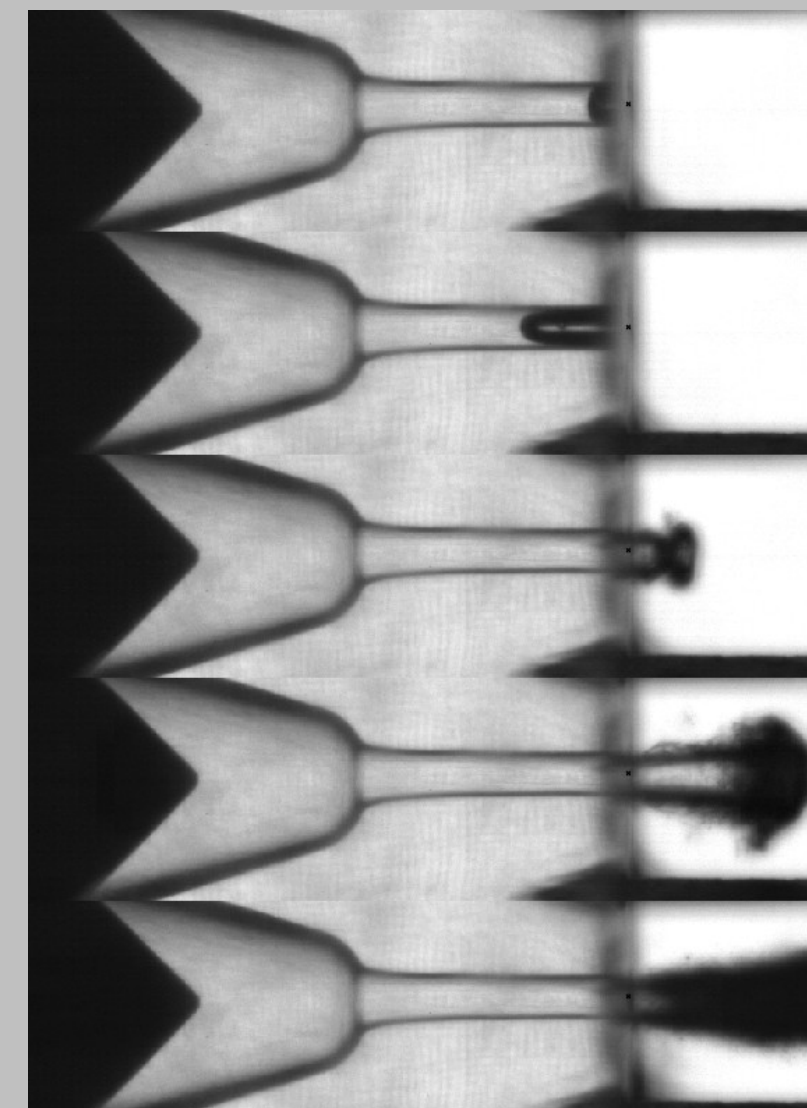


## Abstract

The previous setup for the transparent nozzle injection spray investigation had no ability to simulate the expansion of a car engine. After adding a solenoid valve pressure system that allows depressurization of the vessel, it was shown that the splash back was greatly reduced and that air bubbles could be removed from the sack and nozzle tip of the system. Pressure data collected shows the pressure change in the system versus time during the expansion simulation and the system now has the capabilities to include a dynamic back pressure for injections.

## Injection

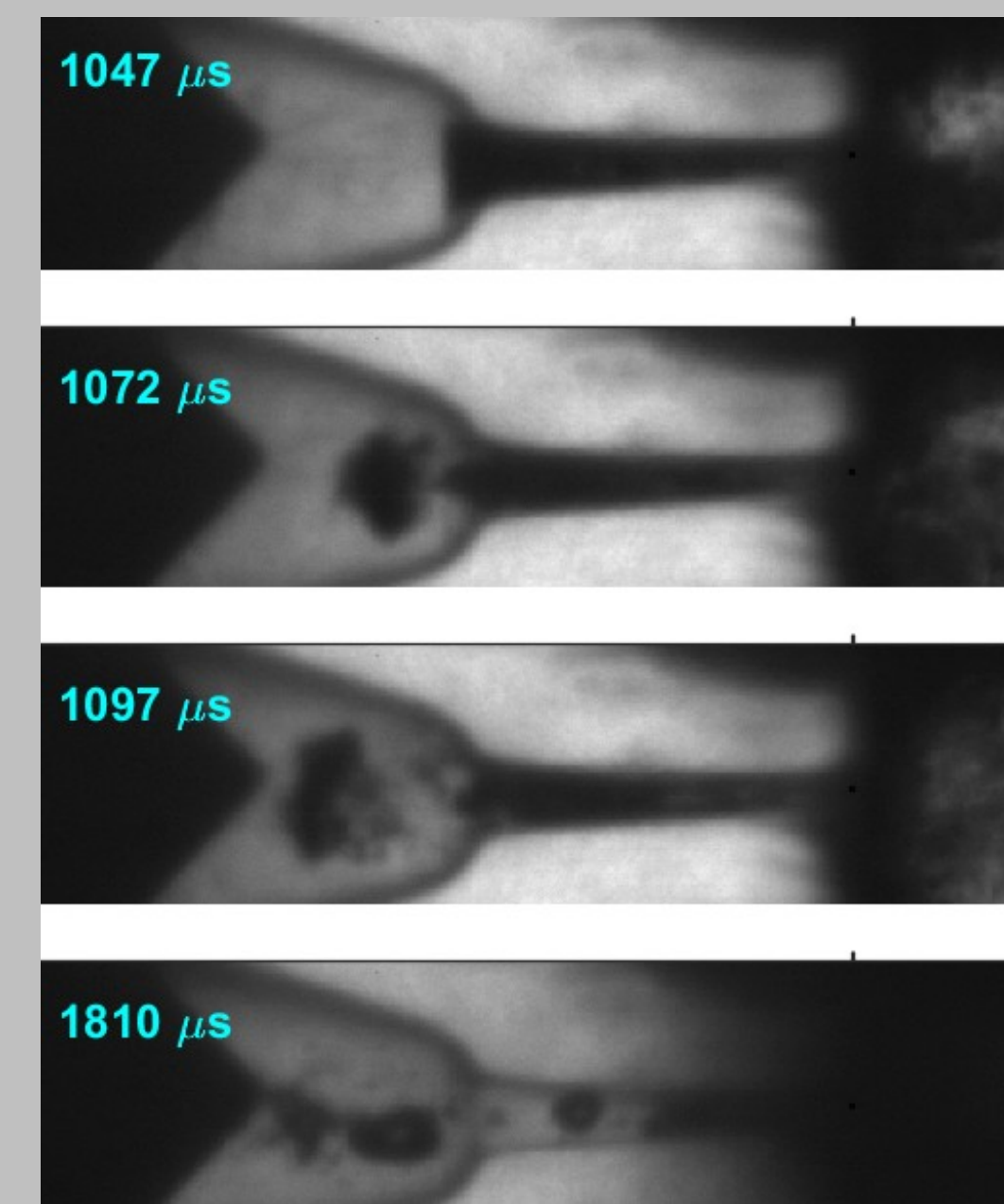
As the injector opens, air is sucked from the spray chamber into the nozzle tip. Then the high pressure fuel flows from the injector through the chamber and into the spray chamber. A liquid core can be seen in the base of the spray.



Images for Injection Spray

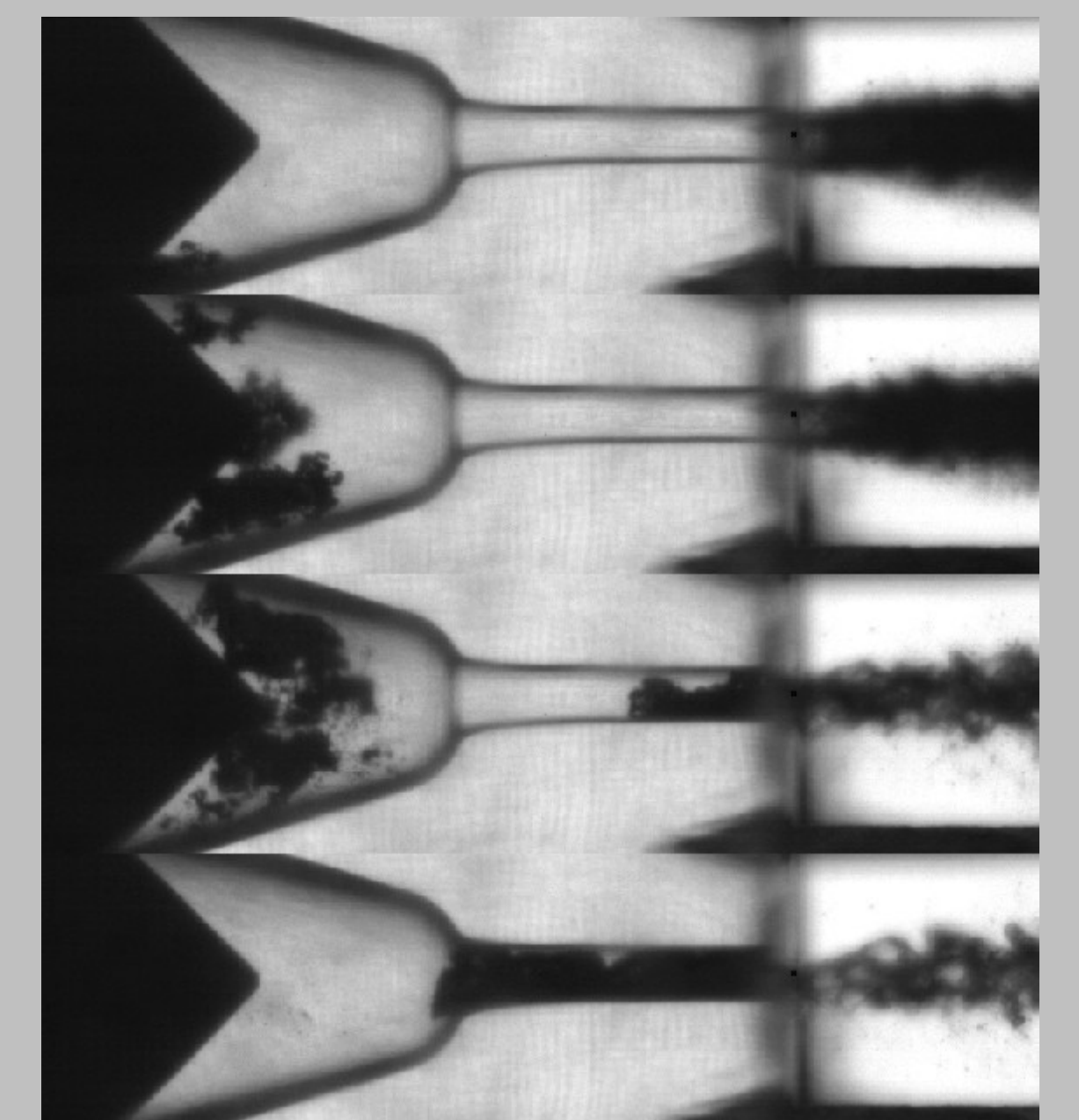
## Splash Back

### Before



Images for Previous Splash Back

### After

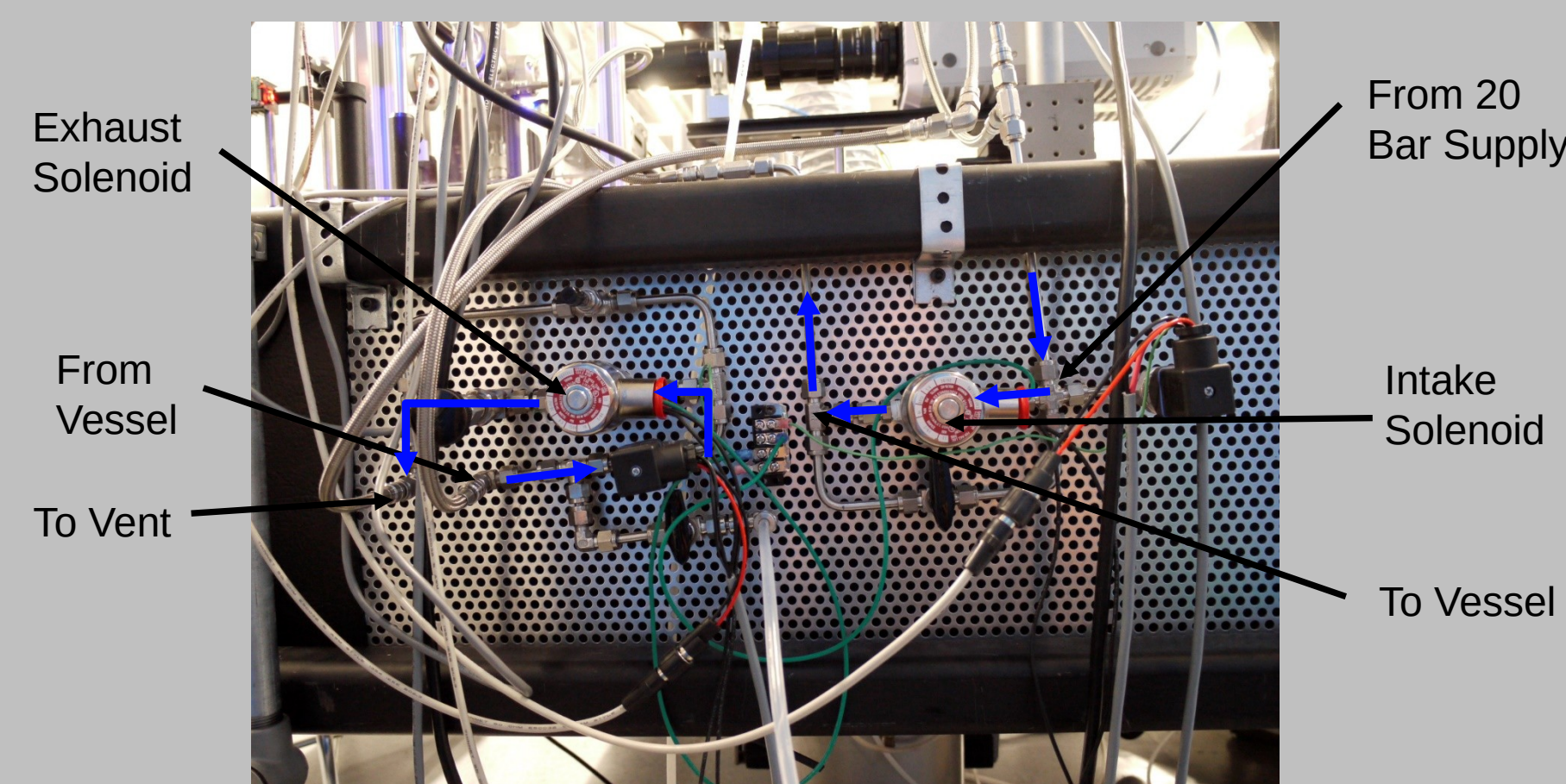


Images for Current Splash Back

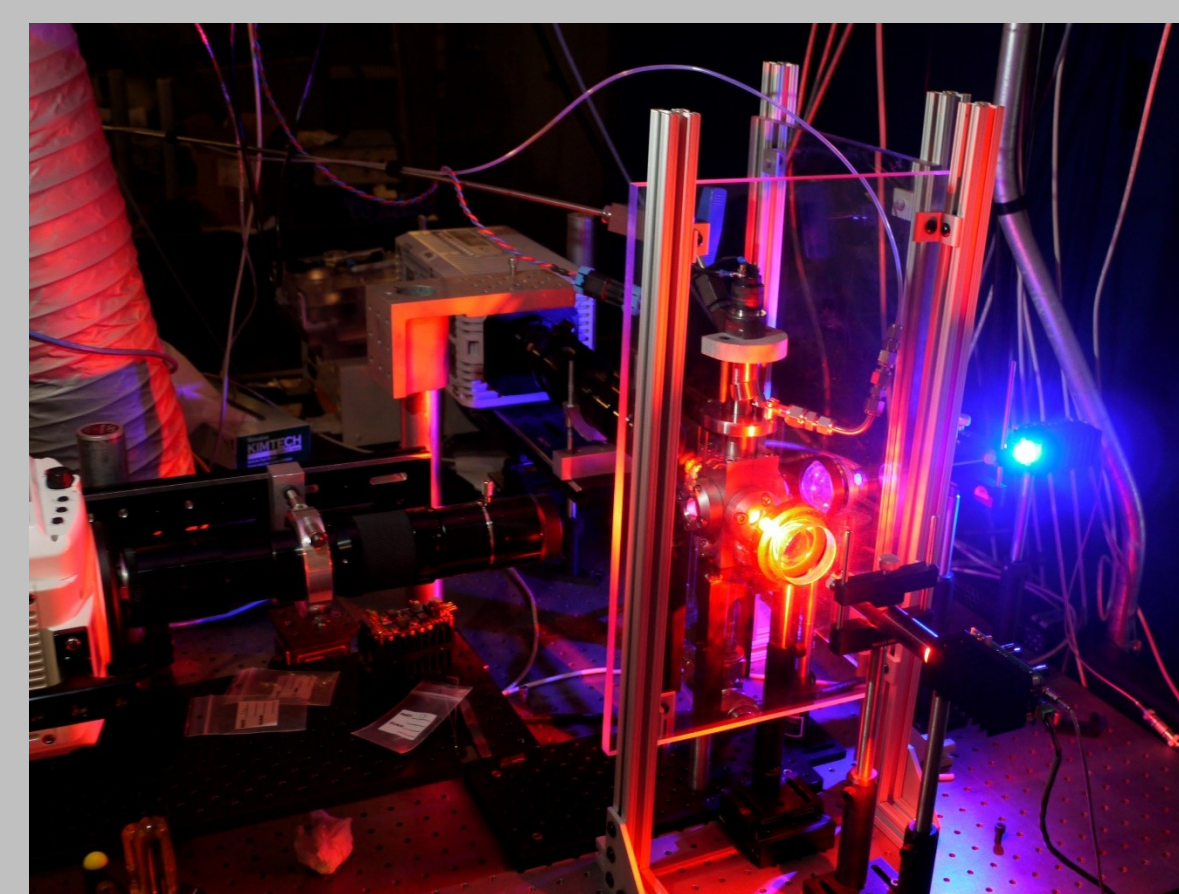
The images above show the spray as the injector closes. An interesting phenomena occurs when the injector is closing, In the after section, there is nothing found in the sack. As the injector closes, there occurs a large growth of black area, these shadows are from a vacuum that has formed from cavitation. As the liquid then moves into the vacuum areas, air is pulled from outside the nozzle into the nozzle tip.

In the old setup, before the expansion simulation was added, there was significant splash back that obscured the camera's view drastically. After adding the expansion simulation setup, the spray chamber had much less splash back and the camera's view was no longer obscured.

## Experimental Setup

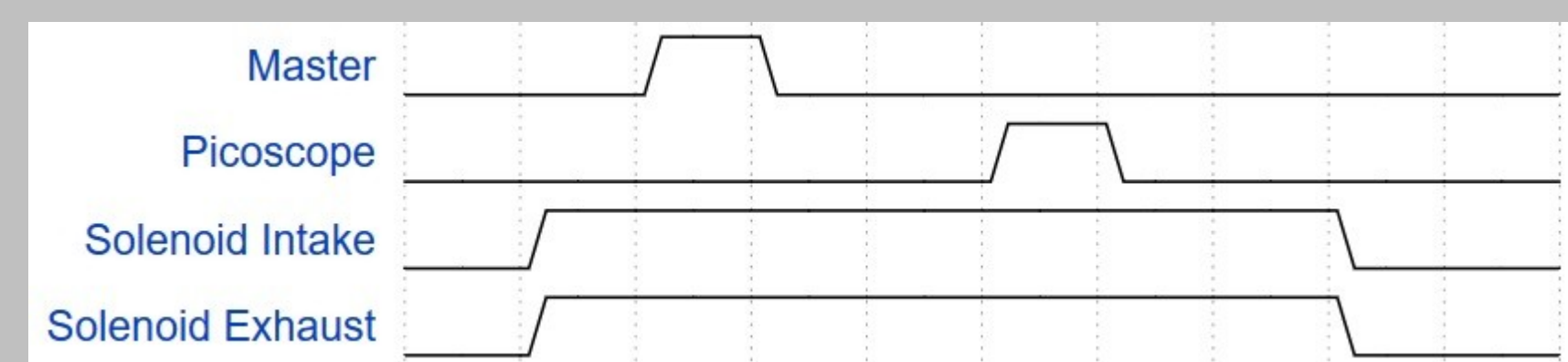


Valve System Used for Simulating Car Engine Expansion (Blue arrows show air flow when all solenoid's open)



Setup of Expeiment with Cameras, LEDs, Blast Doors, and Vessel

Before any devices are triggered, the intake solenoid is open and the exhaust solenoid is closed. The intake solenoid's input is connected to 20 Bar and the exhaust solenoid's output is connected to vent. Upon initial trigger, the intake solenoid closes and the exhaust opens. This allows the pressure to bleed from the system. Each solenoid has a bypass line to skip the solenoids



Timing Diagram for Triggering Experimental Setup

A trigger is first sent to the solenoids to open/close to start the depressurization because there is a delay in response for the solenoids. The master trigger starts the cameras, LEDs and injection synchronously.

The above setup was used for gathering images of injection sprays with the transparent nozzle. The blue and red LEDs flash in time with each camera opposite such that the LEDs backlight the area of focus for imaging.

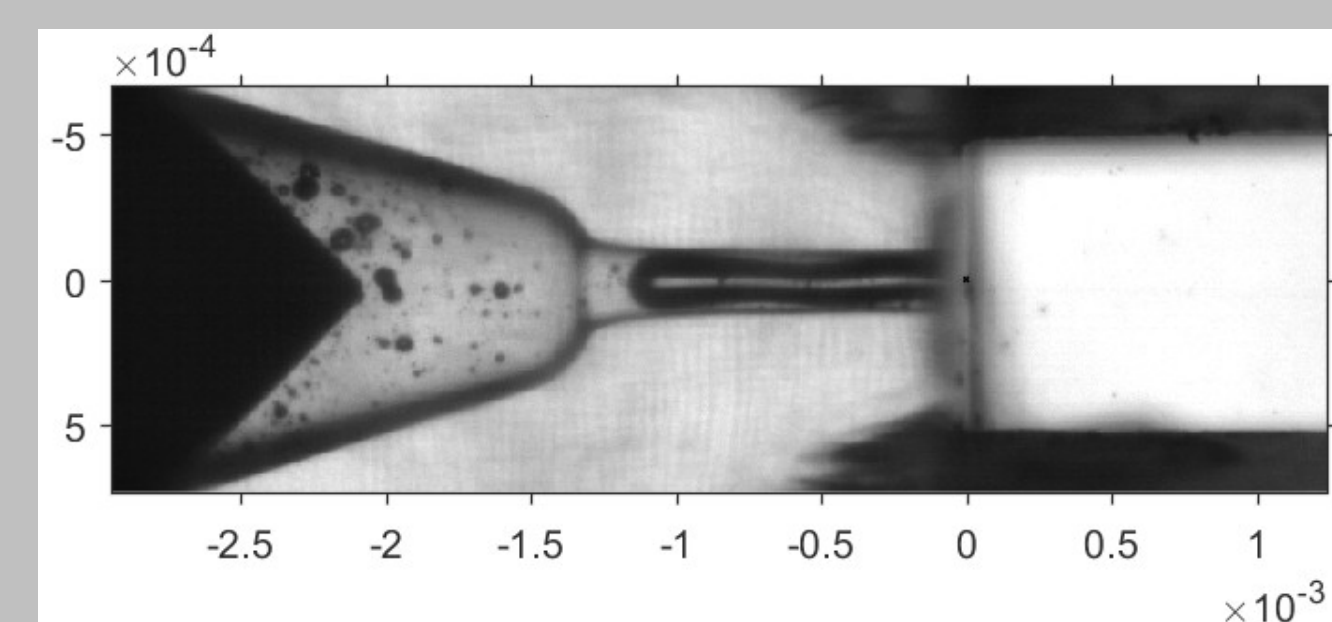
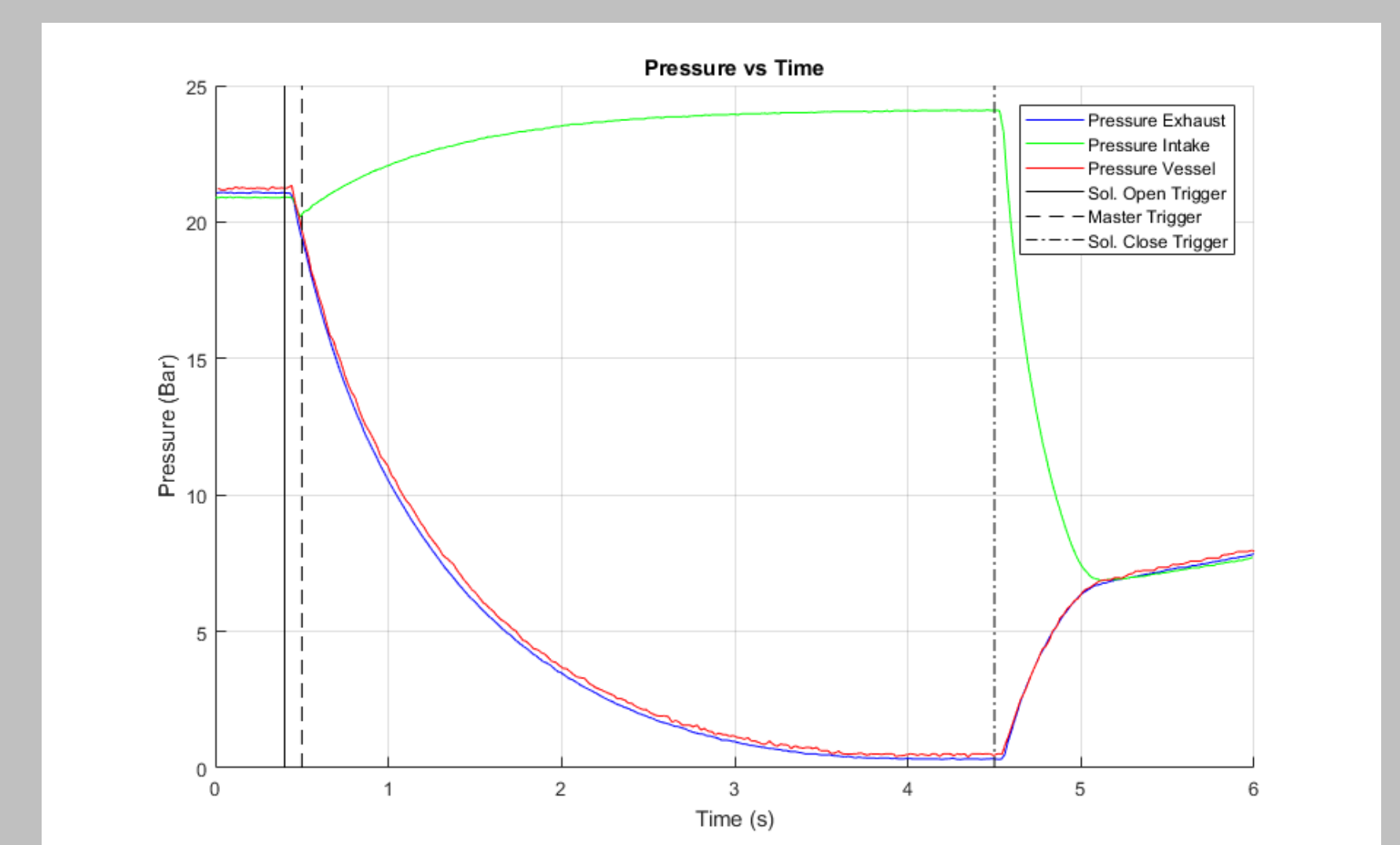


Image Scale

The axis on the image are in meters such that the image is about 1 mm tall and about 4 mm wide. The shadow areas in the sack and nozzle tip are air/vacuum and clear is liquid while in the spray chamber clear is air and shadows are liquid.

## Bleed

The graph shows that the pressure was successfully able to be decreased with the solenoid valve setup. The solenoids were triggered early due to their delay so that the injection was triggered into an already depressurizing system which helped limit splash back. The current system now allows a user to simulate successive expansion and compression cycles of a car engine by changing the trigger times for the solenoids.



Graph of Pressure versus Time

The first image is about 50 ms after injection where the system has settled down and cavitation has pulled some air into the nozzle tip and sack. The second image is after 300 ms and it shows that the first air bubble has already been successfully pulled out of the nozzle tip and that the second is being stretched as it is also pulled on. The third image occurs at a little under one second after injection and shows the second bubble being pulled out of the nozzle tip as the spray chamber continues depressurizing,.



Images for Air Bubbles being "Sucked" Out of Nozzle

## Conclusion

The new system was successfully constructed and setup. Data collected showed the new system helps limit splash back and pulls the air bubbles formed from cavitation out of the sack and the nozzle tip.

## Acknowledgments

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