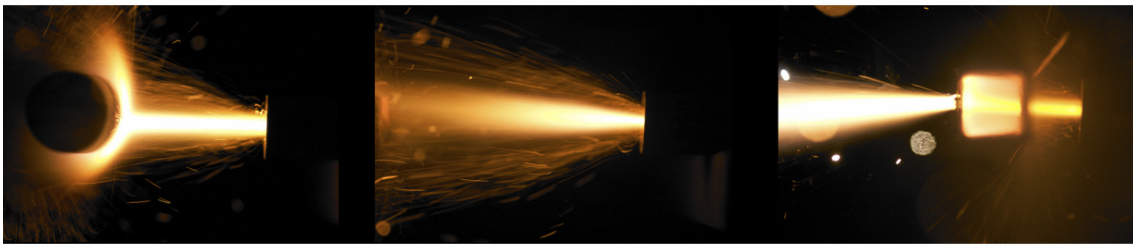
Rocket Engine vs. Steel Tube
Group ETA: Project 2



Purpose

The purpose of these images is to show the flow of the burning rocket fuel as it interacts with different solids. The images to the left and right show a laminar jet flow interacting with differently shaped solid objects.

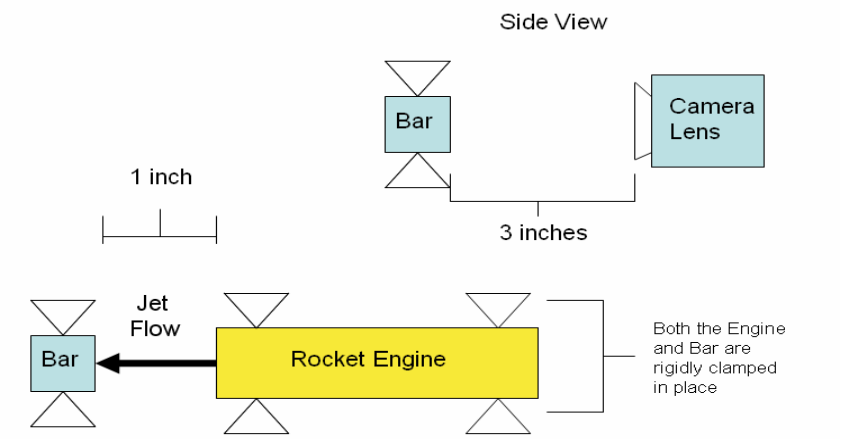
Description of Flow and Apparatus

The flow burns through a square aluminum bar on the right, dies out as it runs out of fuel in the middle, and burns around an aluminum bar to the left. In all images the flow is laminar with Re<<2300. As the flow is obstructed by a solid object or slows due to lack of fuel, it is observed to become less laminar. Reynolds number at this point is closer to 2300 but still laminar. Proportionate to Reynolds number, the speed of flow is far too great to allow anything but laminar flow. Unfortunately the shutter speed used was not quick enough to accurately estimate the fuels speed. However, judging from the visible paths of the burning fuel particles and the shutter speed of the camera, the velocities minimum speed can be estimated. From here we know the flow is traveling at a velocity much greater than 22.5m/s. As the flow is obstructed or runs low on fuel you can see where many particle paths end and their relative velocity have decreased.

Assuming the images were taken at max thrust (12.1N, see table below) we can estimate the acceleration in these images with: (Force/mass) =acceleration. The acceleration in each image is 1940m^2/s, far to fast for a 1/750sec shutter image to capture.

Prod. No.	Engine Type	Total Impulse	Time Delay	Max. Lift Wt.		Max. Thrust		Thrust Duration	Initial Weight		Propellant Weight	
		N-sec	Sec.	0z.	g	Newtons	Lbs.	Sec.	0z.	g	0z.	g
1606	B6-4	5.00	4	4.0	113	12.1	2.7	0.8	0.71	20.1	0.22	6.24

Specs taken from http://ecow.engr.wisc.edu/cgi-bin/get/me/349/bower/estesmodelrocketenginespecchart.pdf



The apparatus used to capture this flow.

Visualization Technique

The lights were dimmed and a black background was used to ensure that the burning jet was the only visible light source. The two solid objects were placed relatively close to the engine (~1in), so the jet stream would be fairly consistent as it contacted the object. The camera was placed just far enough to capture the interaction between jet stream and object (3in). By keeping the camera close to the image a fast shutter speed was still usable without dimming the image.

Photographic Technique

Some slight color profiling was used to heighten contrast. The three images were then stitched together. A high shutter speed was used to decrease blur. ISO and Exposure were high to increase the brightness of the image. Due to the speed of the jet, the fuel particles span over several hundred pixels, displaying there motion within a 1/750 second interval. The image is about 3in from the lens and the field of view is about 1.5X2 inches.

Thrust: 1" Round Steel Pipe		**Thrust: No Obstruction**		**Thrust: Square 1" Aluminum Pipe**	
Image Date	11/2/07 4:12 PM MST	Image Date	11/2/07 4:17 PM MST	Image Date	11/2/07 4:31 PM MST
Camera Model	Canon EOS 10D	Camera Model	Canon EOS 10D	Camera Model	Canon EOS 10D
Serial Number	620312005	Serial Number	620312005	Serial Number	620312005
Shutter Speed	1/750th second	Shutter Speed	1/500th second	Shutter Speed	1/750th second
Aperture	F2.8	Aperture	F2.8	Aperture	F2.8
Exposure Bias	0ev	Exposure Bias	0ev	Exposure Bias	0ev
Focal Length	100mm	Focal Length	100mm	Focal Length	100mm
ISO Speed Rating	ISO 800	ISO Speed Rating	ISO 800	ISO Speed Rating	ISO 800
Aspect Ratio	3:02	Aspect Ratio	3:02	Aspect Ratio	3:02
Orientation	Landscape	Orientation	Landscape	Orientation	Landscape
Depth	16-bit	Depth	16-bit	Depth	16-bit
Color Profile	Adobe RGB 1998	Color Profile	Adobe RGB 1998	Color Profile	Adobe RGB 1998

Conclusions

These images were chosen because they were the most aesthetically pleasing. They accurately capture the laminar flow of a burning jet. There isn't many new physics reveled in these images. We may have got a fresh look into the physics of this flow if we were able to capture the image at a much faster shutter speed. With a faster shutter speed we may have been able to picture the individual particles better. Using a slower jet may also have the same effect. I would also like to explore how the heat from burning affects the flow.