A Planar Detonation Initiator

S.I. Jackson and J.E. Shepherd
Graduate Aeronautical Laboratory
California Institute of Technology
Pasadena, California 91125
jeshep@galcit.caltech.edu

A planar detonation initiator has been developed using a specific geometry of channels to create a planar detonation wave. The device consists of a main channel off of which secondary channels extend perpendicularly. All secondary channels terminate on the same plane, opening into a common test section area. The channel lengths and geometry are such that initiation of a detonation in the main channel results in the wave travelling through each of the secondary channels, exiting them all at the same time. These separate detonation fronts then combine into a planar detonation front, which continues to propagate into the test section. This design is similar to one used (Hill, 2000) for creation of a linear detonation front in high explosives. A CCD camera images the planar detonation wave propagating in the test section. Preliminary results from imaging and pressure trace data indicate that the device produces a nearly planar detonation wave for stoichiometric mixtures of ethylene and oxygen. Images of a reasonably planar wave have been obtained. Currently, the performance with stoichiometric mixtures of propane and oxygen is being investigated.

The device consists of a main channel 16.97 in (431 mm) in length with a width and height of 0.25 in (6.35 mm). A modified aircraft engine spark plug is located at the beginning of the main channel and serves as the ignition source. Internal obstacles machined into the main channel near the spark plug to create turbulence and promote deflagration to detonation transition (DDT) following ignition. Twenty-nine secondary channels extend off the main channel. The linear secondary channels have a square cross section 0.10 in (2.54 mm) in width and are spaced 0.20 in (50.8 mm) apart. Each secondary channel is perpendicular to the main channel. The length of the secondary channels varies such that the total length along any channel from the spark plug to the test section is constant. Thus, all secondary channels terminate on the same exit plane as shown in Figure 1.

The secondary channels exhaust into a common test section 6 in (152.4 mm) in length that gradually expands from the channel exit height of 0.25 in (6.35 mm) to 0.75 in (19.05 mm). Individual detonation fronts exiting from the channels will merge in the exhaust region approximating a planar wave after propagating a few diameters from the channel exits. The test section contains 10 ionization probes and 4 pressure transducers to allow for velocity and pressure measurements. All channels and instrument fittings are machined into a 1.25 in (31.75 mm) thick aluminum plate. The top portion of the device is a window of 1 in (25.4 mm) thick clear polycarbonate, which allows for imaging of the device in operation. Imaging is performed with a CCD camera capable of rapid integration times. Such a setup allows for a snapshot observation of the self-luminosity.

Teflon strips were used as gasket material between the aluminum plate and the polycarbonate window to seal between channels. The high pressures involved in the running of this device necessitate periodic replacement of the gasket material.

Operation is as follows. The entire inner volume is filled with the combustible mixture, which is thoroughly mixed by circulation. Then a weak spark (10 mJ) is discharged across a modified aircraft engine spark plug to ignite the mixture. After a preset delay, the CCD camera images the self-luminosity of the wave front, allowing the detonation to be observed at different stages of development by varying of the delay in separate experiments.

Currently, experiments have been conducted with stoichiometric mixtures of ethylene-oxygen and propane-oxygen at atmospheric conditions. The ethylene-oxygen results show that a nearly planar wave was generated. Pressure traces that are characteristic of a detonation wave were obtained in the test section and appear in Figure 2. Measuring the difference between the time of arrival of the pressure peak on each pressure trace allows determination of the planarity of the wave. Figure 3 shows the wave profile corresponding to the time of arrival of the pressure traces in Figure 2. The maximum difference in arrival time was 0.8 μs between pressure transducers 1 and 2. This corresponds to a spatial distortion of approximately 0.0748 in (1.90 mm) on the wave front as shown in Figure 3. An image of the ethylene-oxygen planar detonation wave was also obtained for the above mentioned pressure traces and wave profiles and is shown in Figure 4.

Preliminary results obtained for stoichiometric mixtures of propane-oxygen are similar to ethylene-oxygen results. Future tests will involve exploring the effects of varying the initial mixture pressure and equivalence ratio.

References

Hill, Larry. Personal communication. April, 2000.

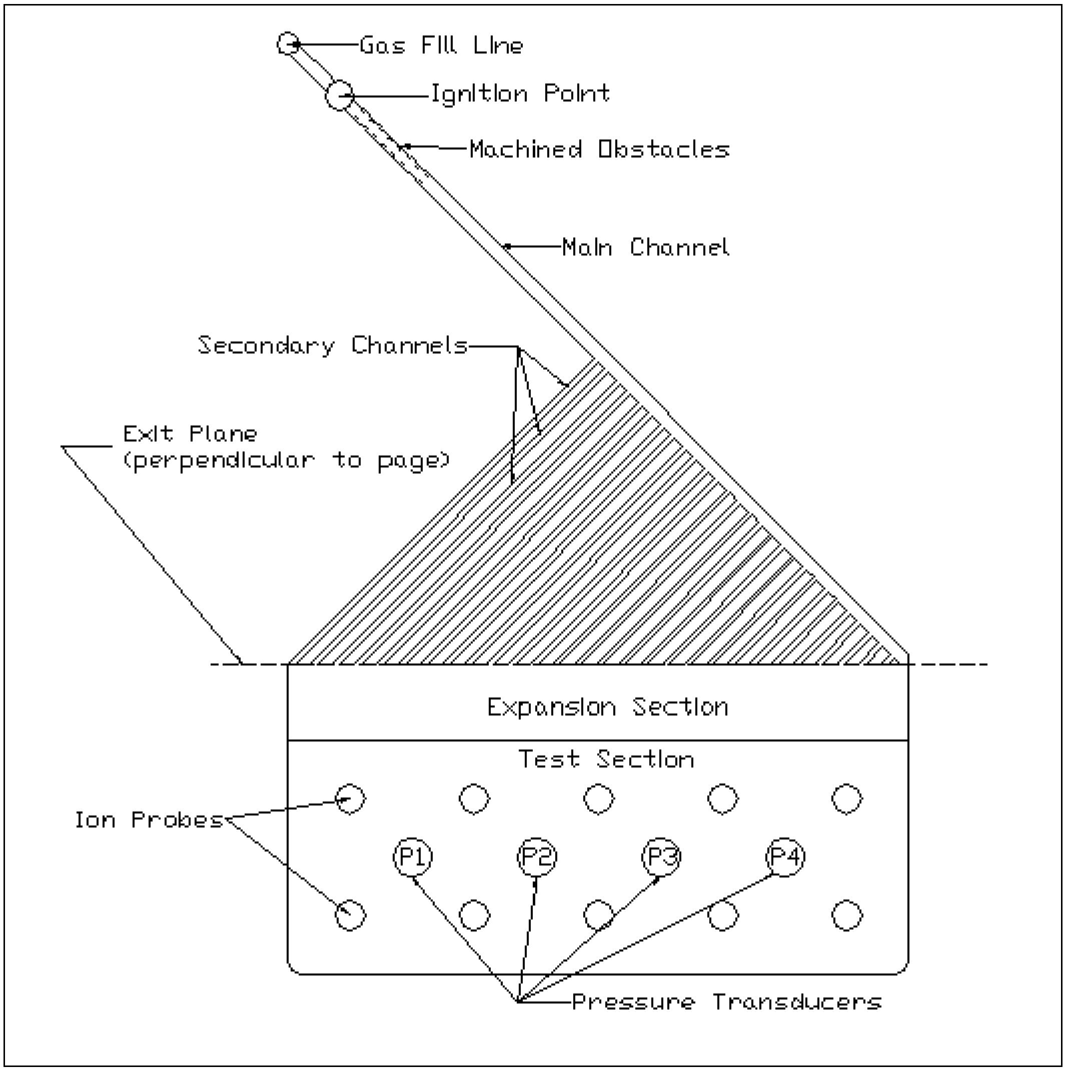

Figure 1: Channel Geometry

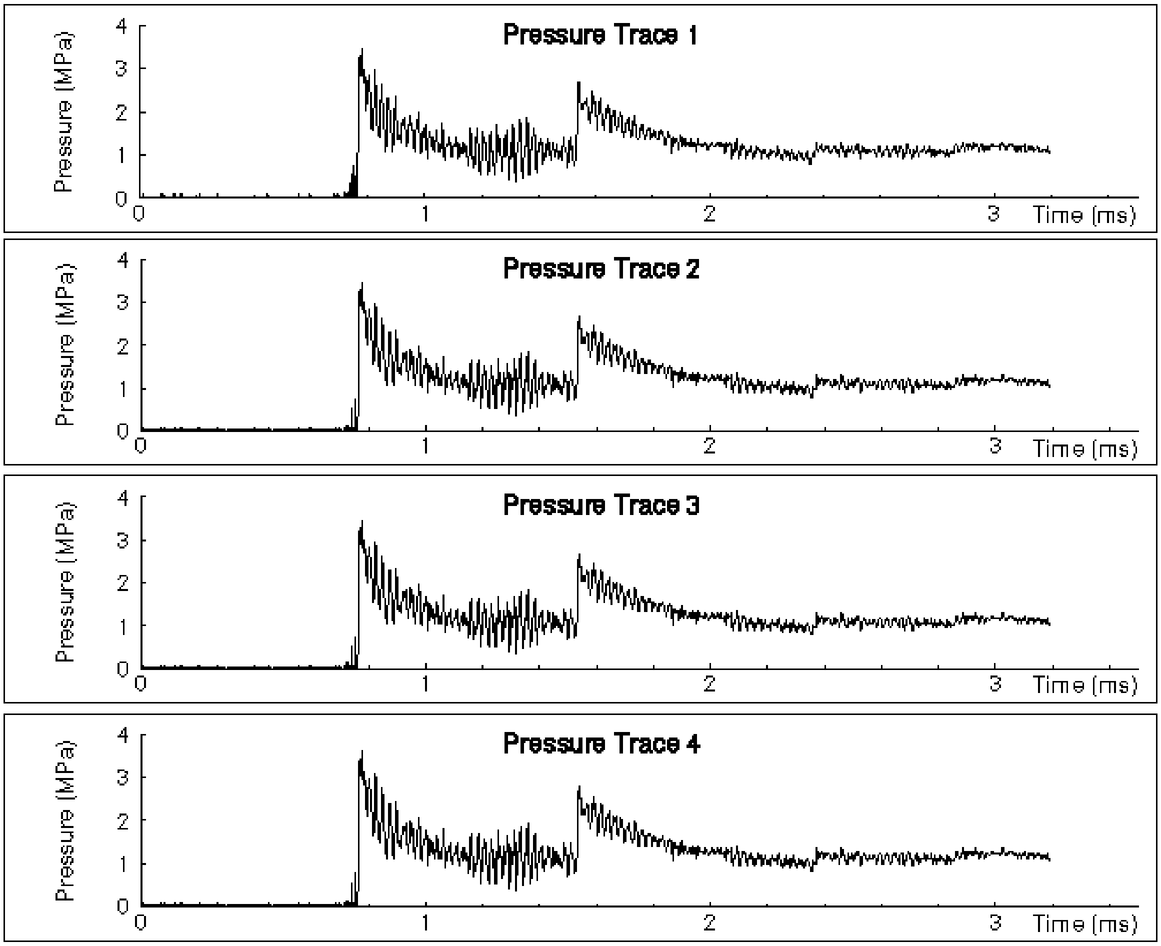

Figure 2: Pressure trace data for $C_2H_4 + 3O_2$ mixture at P_1 = 100 kPa

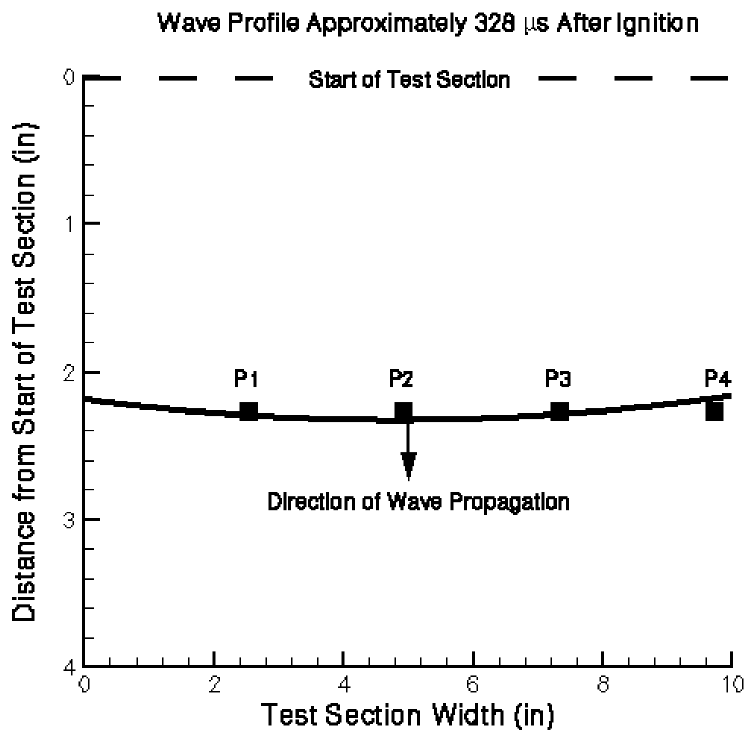

Figure 3: Wave profile corresponding to pressure traces in Figure 2

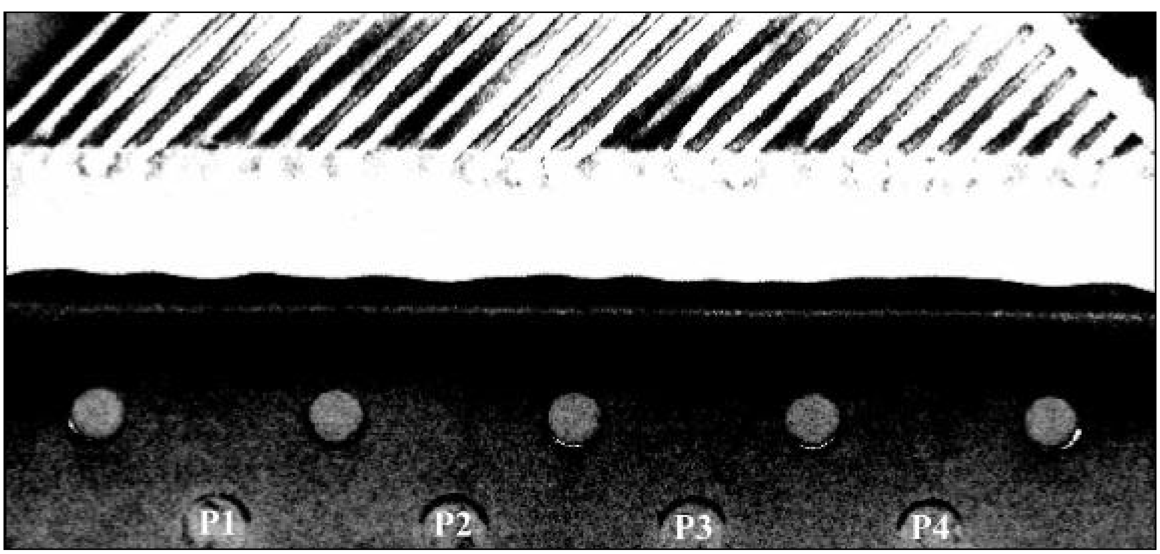

Figure 4: Planar detonation wave corresponding to pressure traces in Figure 2