Documentation of Development for a Coaxial Swirl Injector in a Single Element Engine:

**Combustion Instability with a Single-Element Swirl Injector - Kevin Miller et al.:**

Key Quotations:

*“Because this initial region [of coaxial swirl injectors] is recessed from the injector face, it is shielded from transverse waves and the intra-element dynamics respond only to local variations in the pressure. Thus it may be possible to characterize both fundamental and relative stability characteristics of the pressure-sensitive element through an experimental investigation of its response to longitudinal modes, which can be varied while maintaining fairly constant mean flow effects.”*

*“It is hypothesized that the full-scale stability characteristics of so-called “pressure-sensitive” injector elements, where fluid mechanic effects that occur inside the injector (intra-element effects) dominate the combustion instability mechanism, may be revealed in a carefully designed single-element experiment.”*

*“In this experiment, a moderate pressure, decomposed hydrogen peroxide/kerosene element was tested. The use of the decomposed hydrogen peroxide as the oxidizer simulates the warm oxygen propellant in the oxidizer-rich staged combustion cycle (used with the RD-170) and allows for operational simplifications in test preparation and ignition since the JP-8 fuel can be auto-ignited.”*

Notes:

This paper documents purposefully induced instabilities in a coaxial swirl injector, with several modifications to exacerbate said instabilities. Immediately, several key uses present themselves, chiefly that if we \*don’t\* do these things in our construction, we may achieve a more stable combustion in our own injector.

A primary purpose of the paper was to determine the feasibility of smaller-scale single-element engine tests to predict efficacy and stability of multi-element engines, which was determined to be most effective in the case of injectors depending primarily on intra-element interactions (behavior independent of surrounding area, influenced chiefly by the injector’s internal design) – a criteria coaxial swirl injectors happen to meet very well, making any potential coaxial swirl injector hold implications for the Florida Rocket Lab’s development of a hypothetical future multi-element engine.

The principal actions taken by the researchers to initially cause instability are:

* *“The primary tactic was to acoustically couple the gaseous oxidizer post and combustion chamber. This acoustical coupling involved constructive interference by setting the oxidizer post length appropriately. The oxidizer post length was set during the initial design of the combustor with the intent of obtaining acoustic coupling with the second longitudinal mode of the combustion chamber at a chamber length of 63.5 cm (25 in.).”*
* *“Minimal damping of upstream traveling pressure waves was created by providing an efficient flat reflective surface at the closed end of the oxidizer post.”*
* *“A short nozzle, less than 5% the length of the shortest chamber tested, was used to provide minimal damping of downstream traveling waves.”*

Of course, the natural reaction to these things is to avoid acoustically coupling the gaseous oxidizer post and combustion chamber [How does this work?], making a poorly reflective surface at the closed end of the oxidizer post to dampen upstream-traveling pressure waves, and engineering a long nozzle to similarly dampen downstream traveling waves – these actions should decrease instability in the injector if they can be properly accounted for.

The measurements and experimental outcomes of both the firing tests and the injector flow tests are valuable quanta and should be noted in due time when the prototypes are developed, but are currently not valuable to our research.

Exceptions:

*“The oxidizer enters an annular manifold and is introduced radially, with no swirl, into the oxidizer injector post near the midpoint of this 17.1 cm (6.72 in.) long, 2.05 cm (0.81 in.) diameter tube. A relatively large pressure drop (greater than 50% of the mean chamber pressure) is incurred across the radial inlets to decouple the manifold from flow disturbances occurring downstream in the combustion chamber and oxidizer post. The gaseous oxidizer flows axially through the tube and comes in contact with an annular sheet of swirling fuel that is stabilized on the outer injector wall at a diameter of 2.31 cm (0.91 in.). The JP-8 fuel sheet is initially sheltered from the gas flow by a 0.889 mm (0.035 in.) thick oxidizer post tip. Propellant mixing is initialized inside the element along the 5.08 mm (0.20 in.) recess between the end of the oxidizer post tip and the injector face.”*

The above excerpt distinguishes the fuel injector of the experiment from the specific swirl injector we would use – chiefly it is a liquid-gas injector, whereas our propellants should both be liquid at the point of entering the combustion chamber [revise if necessary]. The lack of an oxidizer swirl in the test is contrasted with the swirl we will impart onto the nitrous oxide in ours – a change with unclear ramifications for the moment. If nothing else, it will be resolved experimentally.

An important paper to review is the following, currently locked behind a paywall (I love for-profit research I love for-profit research I love for-profit research) – it contains important considerations of what could go wrong in such an injector: <https://doi.org/10.2514/6.1993-1953>