Micro-Channel Recuperator and Mixer for FASTER (Feasibility of Acceptable Start Time Experimental Reactor) Autothermal Reformer

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Introduction

The objective of the FASTER (Feasibility of Acceptable Start Time Experimental Reactor) project is to build and test an experimental fuel processor with an acceptably short cold start-up time. The system will utilize an autothermal reformer (ATR) with water-gas shift (WGS) and preferential oxidation (PROX) reactors. Between the outlet of the ATR and the entrance to the WGS reactor is an assembly being provided by PNNL which is the subject of this poster. The assembly is designed to fit within the FASTER geometry and contains two primary components.

The first component is a recuperator in which heat is extracted from the ATR reformate to preheat the air and steam feed to the ATR. This cools the reformate to a temperature suitable for the WGS catalyst. The heat recovered from the hot reformate allows the system to operate in an energy efficient manner.

The second component is a microchannel mixer which is positioned at the reformate outlet from the recuperator. During startup, it is planned to mix air with the reformate and allow oxidation of reformate to occur on the WGS catalyst. The heat generated will allow the catalyst to be brought to temperature rapidly. Variations in oxygen concentration entering the WGS catalyst during startup could lead to local conditions in the WGS catalyst that either (a) result in inadequate heating to achieve the desired activity in the allotted start-up time, or (b) result in overheating and possible damage to the WGS catalyst.

Micro-Channel Recuperator and Mixer for FASTER (Feasibility of Acceptable Start Time Experimental Reactor) Autothermal Reformer, (continued)

Recuperator

The micro-channel recuperator was designed to meet the performance specifications shown in Figure 1. For design purposes the operating pressure was assumed to be 16.7 psia.

In addition to the requirements placed on thermal performance, it was required that the temperature leaving the recuperator be very uniform to avoid uneven temperatures at the inlet to the WGS reactor. In addition, there was a desire to minimize the thermal mass of the recuperator to enable rapid start of the system. Finally, the entire assembly must fit within a 6-inch diameter cylinder while allowing for numerous tubes to carry process streams and instrumentation within an insulated region occupying the outer perimeter of the 6-inch cylinder.

While not specified, the turndown performance of the recuperator is important to the overall system in order to maintain efficiency while operating at less than full load conditions. The turndown performance is shown in Figure 2.

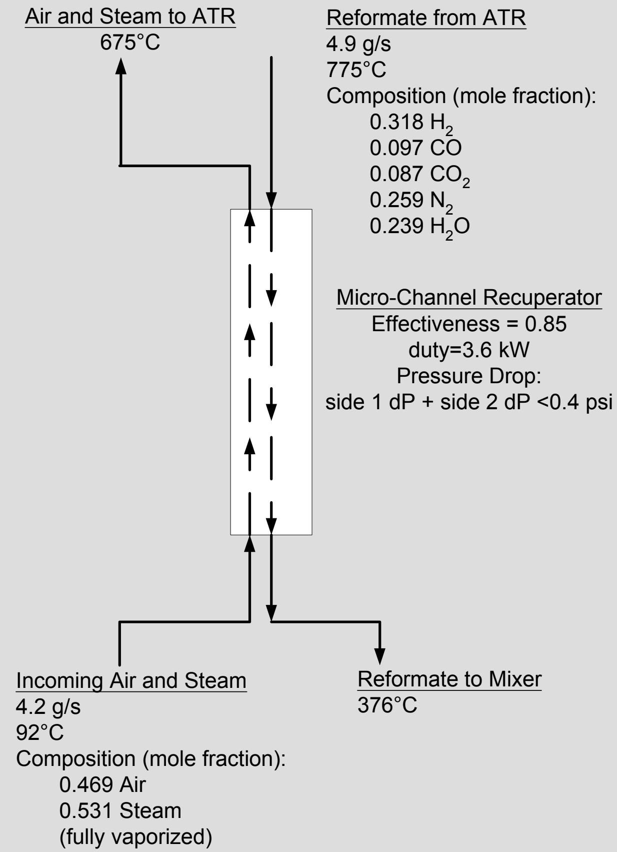

Figure 1. Performance Requirements for Recuperator.

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The recuperator is constructed using Inconel 600 to provide high temperature compatibility. The fabrication process will consist of photo-chemically etching patterns into thin Inconel sheets. The sheets are stacked and then diffusion bonded. During diffusion bonding the etched sheets are sealed to one another and the etched patterns form flow channels. Flow within in the heat exchange channels is laminar.

For rapid startup it is desired to minimize the thermal mass of the recuperator. The mass of the recuperator itself is estimated to be ~800 g. After adding tubing and ducting the weight is increased to 1100 g.

Mixer

The mixer utilizes laminar flow channels to uniformly distribute a flow of air into the reformate stream during startup. It is constructed in 316L stainless steel by bonding a stack of photo-chemically etched plates. The mixer is estimated to weigh 176 grams.

Complete Assembly

The assembly as it will look when delivered to ANL for incorporation into the FASTER reforming system is shown in Figure 3.

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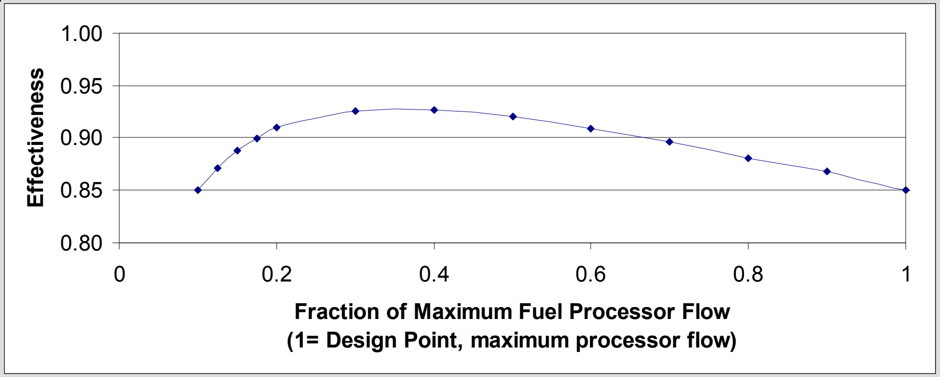
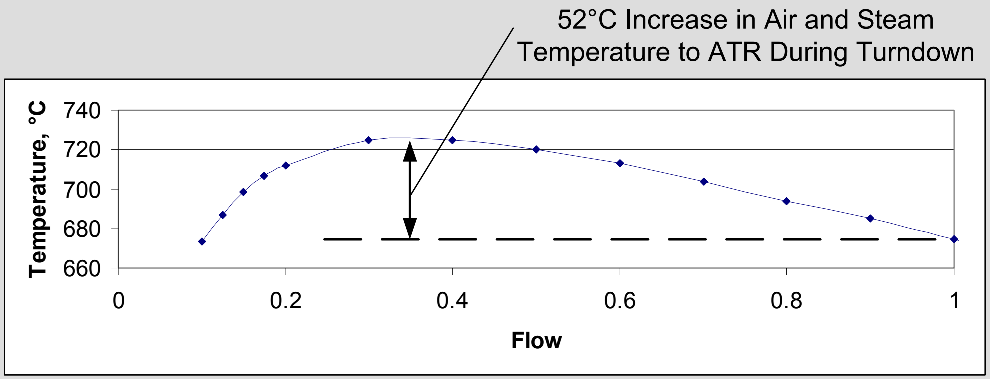
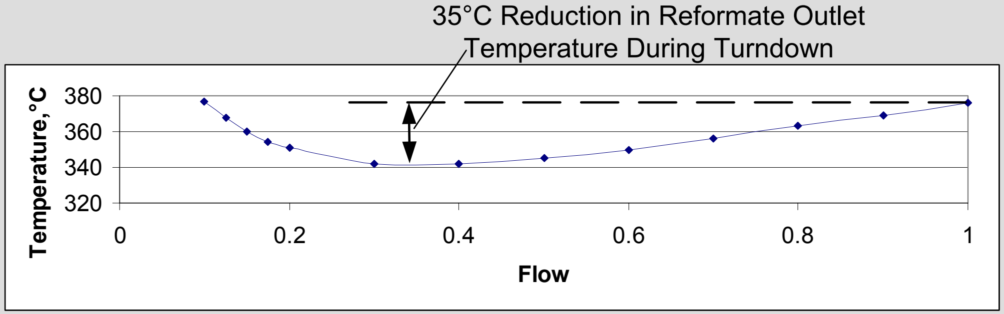


This plot illustrates the variation in effectiveness as the total flow through the two sides of the exchanger are reduced proportionally from full capacity (1.0)



This plot illustrates the impact of turndown on the cooled reformate outlet temperature. Limiting variation is important to prevent adverse impacts on the WGS reactor.



This plot illustrates the impact of turndown on the superheated air and steam temperature The temperature does not decrease below the design point over the 10% to 100% capacity range.

Figure 2. Recuperator Turndown Performance.

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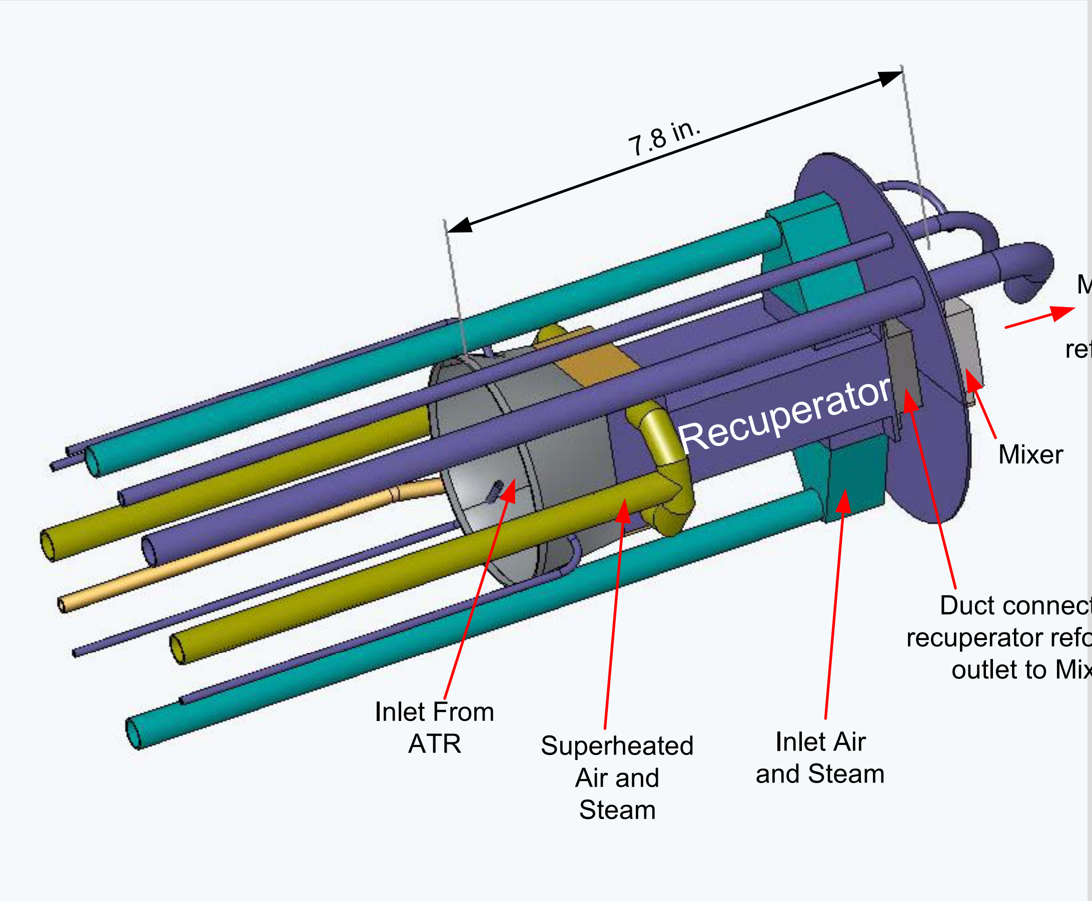
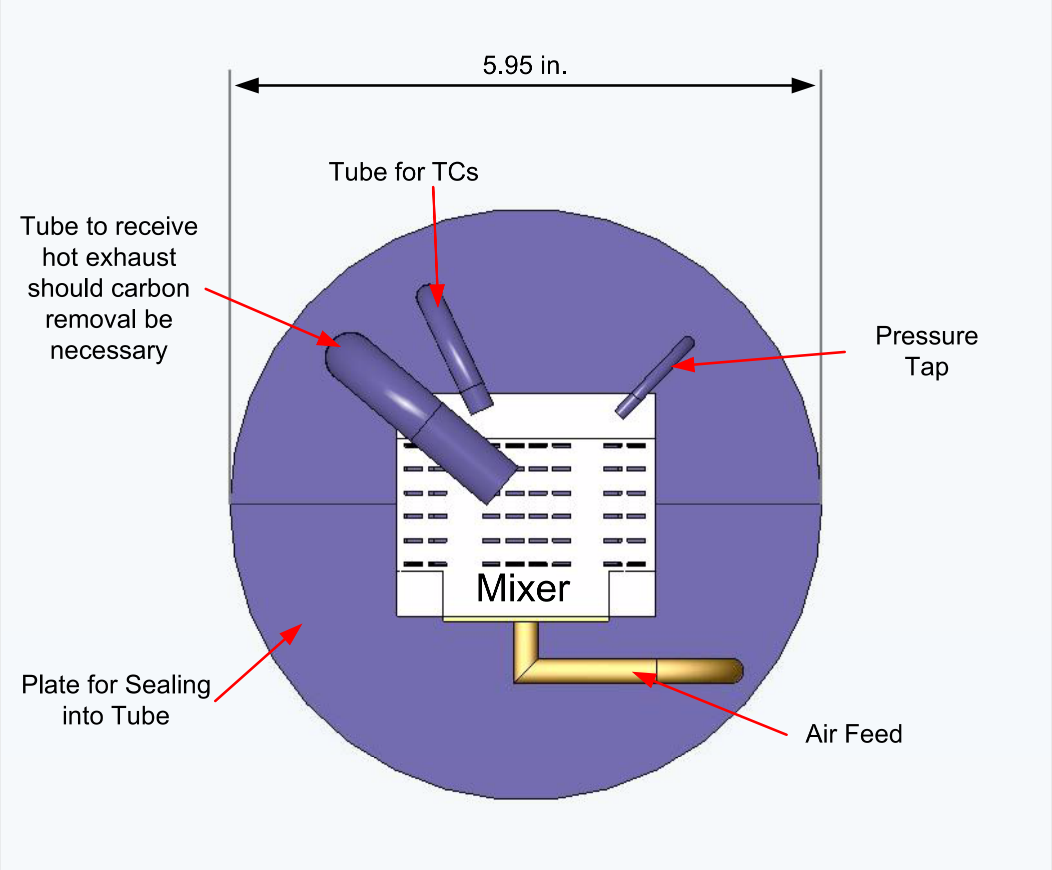


Figure 3. Recuperator/Mixer Assembly.

Micro-Channel Recuperator and Mixer for FASTER (Feasibility of Acceptable Start Time Experimental Reactor) Autothermal Reformer, (continued)



View of assembly from the reformate discharge end. Slots in the mixer are for illustration only and are finer than shown.

Figure 3. Recuperator/Mixer Assembly, continued.

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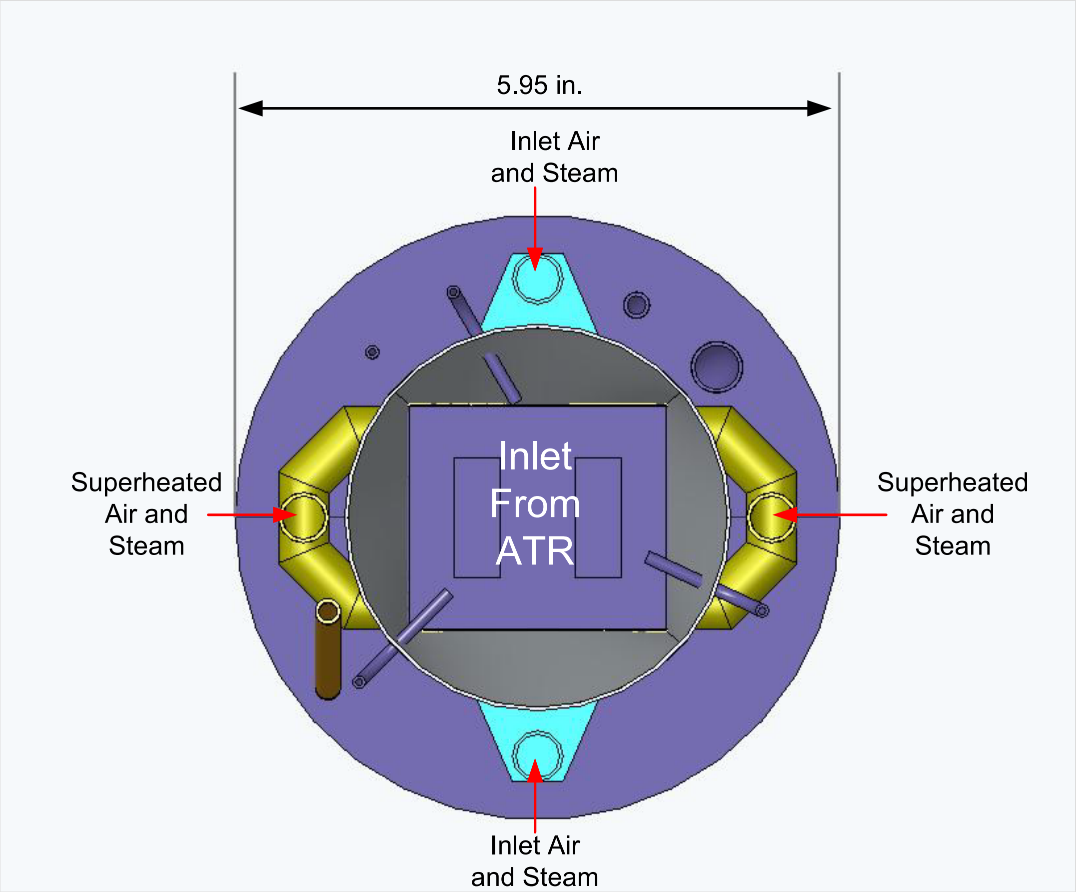

View of assembly from the reformate inlet end.

Figure 3. Recuperator/Mixer Assembly, continued.