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Supercritical CO_2 Main Compressor Performance Measurements

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INTRODUCTION

Sandia Labs and the DOE Gen IV program are developing test hardware to understand the fundamental issues of supercritical CO_2 (SCO2) Brayton cycles. This testing is part of a phased development effort that will construct a one MW heater-class Brayton cycle with a split-flow or re-compression SCO2 Brayton cycle. This power conversion cycle is being investigated because it operates at high cycle efficiency at modest turbine inlet temperatures (eff=43% at 538 C), and it is extremely small because of the high density of the supercritical CO_2[1].

This paper describes early test results of the main compressor performance and compares it with the model predictions. The testing shows that the main compressor operates reliably and stably over a wide range of operating conditions including operations at the critical point, above the critical conditions, and on the saturation curve. The main testing has focused on measuring the main-compressor performance maps. During these tests Sandia was able to measure other important data such as thrust loads, windage effects, seal leakage effects and surge conditions.

DESCRIPTION OF THE SCO2 TEST HARDWARE

A schematic diagram of the motor-driven compressor is illustrated in Figure 1. The loop uses a ~50 kWe motor to spin a 37 mm OD compressor at design speeds up to 75,000 rpm. The loop also has a flow control valve and a gas chiller[2]. The loop was fabricated by Barber Nichols Inc.[3] (Arvada, Colorado) under contract to Sandia.

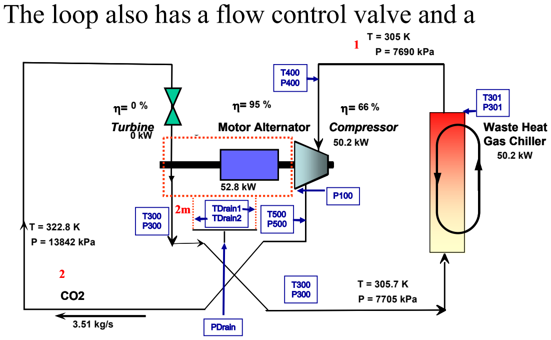

Figure 1: Schematic of Sandia SCO2 Compression Loop.

Figure 2 shows a photo of the radial compressor with the diffuser vanes while the image on the right shows the fully assembled turbomachinery.

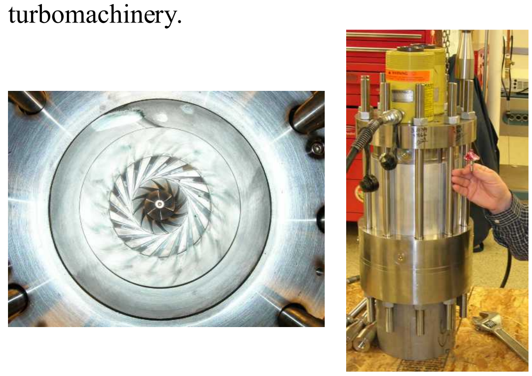

Figure 2: (Left) Main compressor (Right) SCO2 turbomachinery.

MAIN COMPRESSOR PERFROMANCE MAP

In December 2008, the loop was used to measure the main compressor performance flow map. The results of these measured data are compared with the predictions of the compressor performance as shown in Figure 3. The plot shows the specific change in enthalpy as a function of corrected mass flow rate at fixed corrected speeds. This figure shows very good agreement between the models and predictions for specific enthalpy change[4]. Early estimates also show that the measured efficiencies also agree with the predictions. In general, near the operating line, the measured efficiency is within a few percent of the predicted value.

At this stage of testing supercritical compression, the main compressor shows no adverse behavior while operating over a range of conditions. It operates reliably and with performance values that are very near the predicted results.

The basic design and performance for the main-compressor are sound. The compression test loop will be used to support the next stage of development which is a 1 MW heater-class split-flow re-compressor Brayton cycle that will be capable of generating up to 250 kWe.

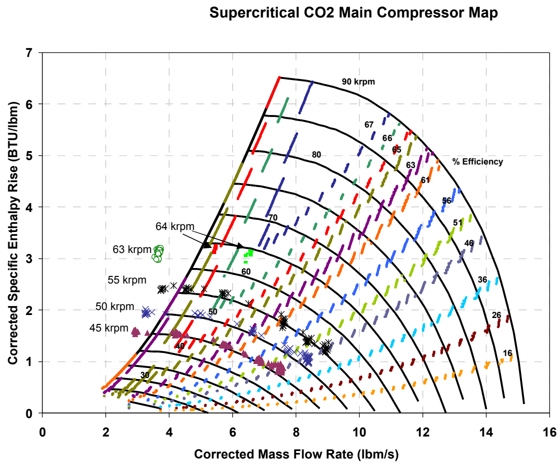

Figure 3: Experimental and model comparison of the DOE Gen-IV Supercritical CO_2 main compressor map. The performance map shows corrected enthalpy change as a function of corrected mass flow rate for fixed corrected shaft speed at 45, 50, 55, 63, and 64 krpm.

REFERENCES

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