Supercritical carbon dioxide (sCO2) cycles are being investigated for the future of power generation. These cycles will contribute to a carbon-neutral future to combat the effects of climate change. These direct-fired closed cycles will produce power without adding significant pollutants to the atmosphere. For these cycles to be efficient, they will need to operate at significantly higher pressures (e.g., 300 atm for Allam Cycle) than existing systems (typically less than 40 atm). There is limited knowledge on combustion at these pressures or at the high dilution of carbon dioxide. Nominal fuel choices for gas turbines include natural gas and syngas (mixture of CO and H2). Shock tubes study these problems in order to understand the fundamentals and solve various challenges. Shock tube experiments have been studied by the author in the sCO2 regime for various fuels including natural gas, methane and syngas. Using the shock tube to take measurements, pressure and light emissions time-histories measurements were taken at a 2-cm axial location away from the end wall. Experiments for syngas at lower pressure utilized high-speed imaging through the end wall to investigate the effects of bifurcation. It was found that carbon dioxide created unique interactions with the shock tube compared to tradition bath gasses such as argon. The experimental results were compared to predictions from leading chemical kinetic mechanisms. In general, mechanisms can predict the experimental data for methane and other hydrocarbon fuels; however, the models overpredict for syngas mixtures. Reaction pathway analysis was evaluated to determine where the models need improvements. A new shock tube has been designed and built to operate up to 1000 atm pressures for future high-pressure experiments. Details of this new facility are included in this work. The experiments in this work are necessary for mechanism development to design an efficient combustor operate these cycles.