The studies in this dissertation were conducted using the Rapid Compression Machine (RCM) constructed by Mittal and described in the work of Mittal and Sung [1] and Mittal [2]. This RCM has been used to study the autoignition behavior of a number of fuels, including *n*-decane, methylcyclohexane, hydrogen, syngas, dimethyl ether, methanol, toluene, benzene, di-isobutylene, iso-octane, jet fuel, and gasoline [3–18].

The present RCM is a pneumatically-driven/hydraulically-stopped single-piston arrangement. A schematic of the RCM is shown in **??**. The RCM consists of four chambers and three pistons that are used to control machine. The chambers are called the reaction chamber, the hydraulic chamber, the pneumatic chamber, and the driving tank; similarly, the pistons are called the reactor, hydraulic, and pneumatic pistons and are each installed in the chamber of the same name. The driving tank and pneumatic chamber are connected by a union and the pneumatic piston is sealed to the walls of the pneumatic chamber, so that the pneumatic piston is driven by pressure from the driving tank on its rear and pressure from the pneumatic chamber on its front. The pistons are connected by a rod running from the front of the pneumatic piston to the rear of the reactor piston so that they move as one; this will be referred to as the piston assembly.

At the start of an experimental run, with the piston in the end-of-compression (EOC) position, the reaction chamber is vacuumed to less than one Torr. Next, the piston assembly is retracted by pneumatic pressure on the front face of the piston in the pneumatic chamber. For safety, and to prevent damage to the RCM, the driving tank should be filled to limit the acceleration of the piston assembly during this retraction. The pneumatic pressure on the front of the pneumatic piston pulls the piston assembly rearward and seats the hydraulic piston onto an o-ring in the rear of the hydraulic chamber. Then the hydraulic chamber is filled with oil to a pressure of approximately 800 psi, providing a rearward force on the hydraulic piston. The pneumatic pressure is then released from the pneumatic chamber and the driving tank is filled to the driving pressure. The force on the hydraulic piston opposes the force on the pneumatic piston from the driving tank and the piston assembly remains at rest. Then, the reaction chamber is filled with the required initial pressure of test gas mixture from the mixing tank. The compression is triggered by releasing the hydraulic pressure. The piston assembly is driven forward to compress the test mixture by high-pressure nitrogen gas in the driving tank. The gases in the test section are brought to the compressed pressure ($P_C$) and compressed temperature ($T_C$) conditions in approximately 30 milliseconds.

The required driving pressure for a given EOC pressure can be estimated from a force balance between the force on the pneumatic piston from the driving tank and the force on the reactor piston from the reaction gases, as shown in Eq. (1c).

$$P_{d,\text{min}} \cdot A_p = P_{r,\text{EOC}} \cdot A_r \tag{1a}$$

$$P_{d,\text{min}} \cdot \frac{\pi d_p^2}{4} = P_{r,\text{EOC}} \cdot \frac{\pi d_r^2}{4} \tag{1b}$$

$$P_{d,\text{min}} = P_{r,\text{EOC}} \cdot \frac{d_r^2}{d_p^2} \tag{1c}$$

In Eq. (1), $P_{d,\text{min}}$ is the minimum driving pressure, $A_p$ is the cross-sectional area of the pneumatic piston, $P_{r,\text{EOC}}$ is the pressure in the reactor at the EOC (i.e. $P_C$), $A_r$ is the cross-sectional area of the reactor piston, $d_p$ is the diameter of the pneumatic piston, and $d_r$ is the diameter of the reactor piston.

The minimum driving pressure is such that the piston does not rebound at the EOC due to pressure on the reactor piston. So that the driving pressure can be much lower than the EOC pressure, the diameter ratio of the reactor piston to the driver piston is $2/5$. The actual driving pressure should exceed the minimum by some safety margin so that the reactor remains at constant volume even if there is some pressure rise due to first stage ignition.

There is not a theoretical upper limit on the driving pressure. It is desired that the piston should reach the EOC conditions in as short a time as possible to minimize heat loss from the reactants to the reactor walls and minimize the time for reactions to occur during the compression stroke. This implies that the driving pressure should be made as high as possible so that the highest piston velocity is achieved. However, higher piston velocities require a higher deceleration at the EOC. In the present RCM, the deceleration is provided by venting the hydraulic oil between steps on the hydraulic piston and matched steps on the front of the hydraulic chamber. If the piston is "overdriven" - that is, the driving pressure is too high - the piston will not be sufficiently decelerated by the oil venting and will impact the front of the hydraulic chamber at high velocity. This can damage the RCM and cause the piston to rebound elastically. It also generates substantial noise in the pressure trace and should be avoided.

Typical driving gas pressures are between 50 psi for $P_C = 15$ bar experiments to $P_C = 125$ psi for 50 bar experiments. These driving pressures represent a good compromise between the minimum required for no rebound at EOC due to pressure and no rebound at EOC due to elastic reaction. Nonetheless, a small amount of piston rebound can be expected during/after the main ignition event as the driving pressures required to overcome the full pressure rise due to ignition would cause elastic rebound. Thus, this small rebound may have an effect on the computation of ignition delay if it reduces the pressure rise rate during the ignition; it is expected that this effect will be very small relative to the typical random uncertainty in ignition delay experiments.