(roll) axis. As soon as one wing becomes lower than the other, it senses the turn and immediately displays it. This makes it easier for the pilot to coordinate with rudder.

Rigidity in Space

All gyroscopic instruments operate under the same physical properties: rigidity in space and precession. The faster a gyro spins, the greater is its tendency to keep its spin axis in the same direction. Quite literally the gyro inside the instrument maintains a constant position while the airframe moves around it. It is this "rigidity in space" that provides a fixed point of reference for the pilot whose senses are easily misled when outside visual contact with the horizon is lost, such as on a very dark night or when flying in reduced visibility.

The gyro wheel has its bearings in a ring called a *gimbal*. Gyro instruments are gimbaled to permit the gyros to move in specific directions while preventing movement in all others, depending on the purpose of the instrument. The force that causes the gyro to spin may be either air or electricity. Older aircraft, before electrical systems, used a venturi mounted outside the airplane, as seen in Figure 2-14, as a source of vacuum. While it was Bernoulli's principle in its simplest form, there were some significant problems.

Venturi-driven systems were designed to operate at cruise, approximately 100 mph, which prevented any form of preflight check or calibration until after the aircraft was airborne. The venturi, which operates fundamentally the same as a carburetor, suffered from another formidable problem: its high susceptibility to in-flight icing similar to carb ice. There was also the problem of potential foreign object damage because the venturi was

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Fig. 2-14. *Venturi.* (Photo by author, courtesy of Frasca Air Services)