The piston actuator requires some form of mechanism for use on rotary motion valves to convert linear force to torque. This is made easier because the majority of part-turn valves require 90 degrees of movement only and therefore only a short piston movement. There are four types of mechanism available to convert linear to rotary motion.

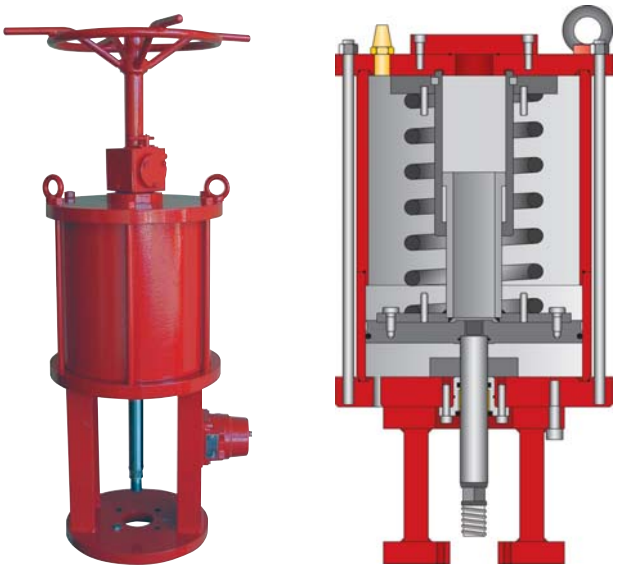

Figure PA2: Pneumatic Piston Actuator for Linear Motion Valves

(a) A scotch yoke actuator consists of a piston, connecting shaft, yoke, and rotary pin (see Figure PA3).The yoke is off set 45o from the axis of the piston at the two ends of travel. At the mid travel position the yoke is at 90o to the piston shaft and the centre of rotation is closest to the shaft. The fact that the moment arm is the shortest means that the torque output at mid travel i.e. 45o open is a minimum. Figure PA4 hows the output torque characteristics of the scotch yoke actuator both as double acting and as single acting with spring return to the closed position. The torque curve for the single acting is the net curve of the double acting minus the spring return curve. The minimum torque on the spring return curve is no longer at the mid travel because of the fact that the spring force is reducing as the valve closes thereby moving the minimum towards the 30° open position.

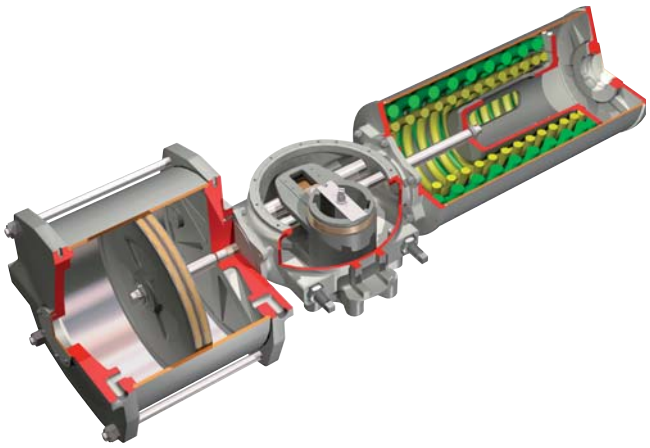

Figure PA3: Section view of a typical Scotch Yoke Pneumatic Actuator (Flowserve)

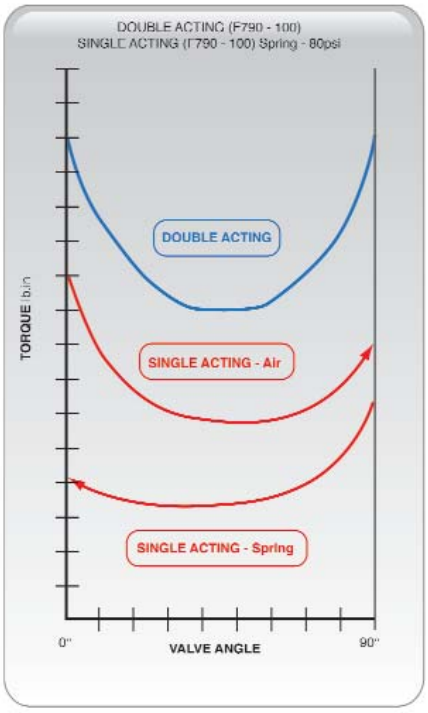

Figure PA4: Torque Characteristics for Scotch Yoke Actuator

A variation of the scotch yoke is the canted scotch yoke (see Figure PA5). By offsetting the axis of the slot in the yoke such that it no longer passes through the shaft axis, the output torque is slewed towards the closed position. This torque curve is particularly suited to the offset butterfly valve.

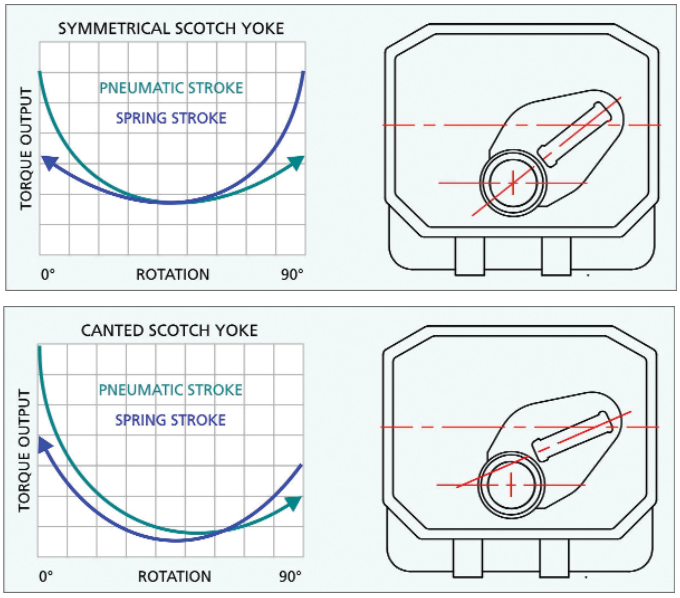

Figure PA5: Symmetrical and Canted Scotch Yoke (Rotork)

(b) The rack and pinion actuator consists of a single or double piston coupled with an integral rack which drives the pinion. The majority of actuators are designed for producing a 90 degree turn on the pinion (see Figure PA6). However, rack and pinion actuators are available which produce 180 degrees output. The rack contacts the pinion at a constant dimension from the centre of rotation and, therefore, the torque output

of a double acting actuator is constant throughout the stroke. This makes this type particularly suitable for plug valves.

Figure PA6: Detail view of a dual opposed, single acting spring return rack and pinion pneumatic actuator (Emerson Hytork)

A rack and pinion actuator may be of the single or double piston design. The double piston is referred to as 'dual opposed' because, as the actuator is stroked, the pistons move inwards towards one another (see Figure PA7). The use of two pistons in this way enables more torque to be provided, as the air pressure is applied to two piston areas simultaneously.

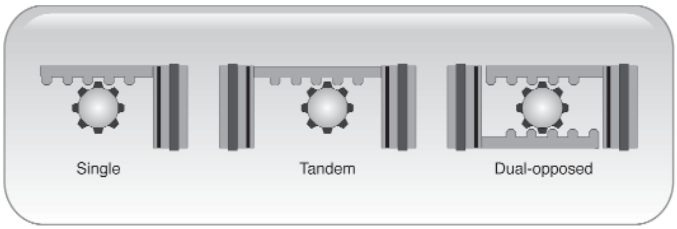

Figure PA7: Rack and Pinion Actuators with Single, Tandem and Dual Opposed Pistons

(c) Trunion/lever arm actuators normally consist of a simple trunion-mounted cylinder with a piston which acts directly upon a lever attached to the valve shaft. Generally speaking, this type of actuator is not popular in view of the fact that there are exposed moving parts which may cause injury to personnel. However, it is possible to use them when they can be enclosed within a suitable guard. The torque characteristics are similar to that of the scotch yoke mechanism in that the length of the moment arm varies with angular position.

(d) A cam mechanism actuator consists of double pistons connected by spacer bars with a cam and shaft between them (see Figure PA8). The rotational stroke is determined by the cam profile, which is in contact with the centre of the pressurized piston face throughout the stroke. The cam profile can be designed to give an exact 90 degrees rotation, alleviating the need for mechanical end stops.

The output torque of double acting cam actuators remains constant throughout the stroke.

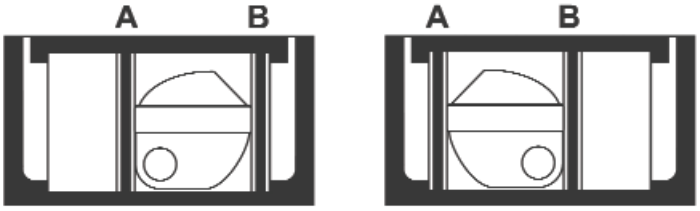

Figure PA8: Double Acting Cam Actuator (Matic Actuators, Div. of Imtex Controls Ltd)

- **Diaphragm actuators** - Another form of linear motion pneumatic actuator is the diaphragm actuator (see Figure PA9). It comprises a rubber diaphragm and stem contained in a circular pressed steel housing. They are usually single acting with air being supplied to one side of the diaphragm and springs providing the return energy. The nature of the flexible diaphragm means that travel is relatively restricted compared to that of the cylinder actuator. They are ideally suited to the shorter maximum travels of diaphragm and globe valves and they can also be used on small gate valves.

  For globe valves spring thrust and travel limitations start to create difficulties if flow is under the disc and spring to close action is required. By reversing the flow direction and thereby using line pressure to assist closure of the globe valve, the range of valve sizes and differential pressure for which this type is suitable can be extended.

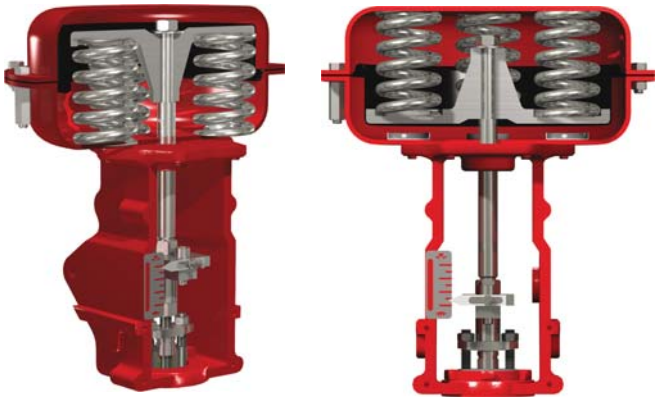

Figure PA9: Pneumatic Diaphragm Actuators, Air Fail Open to LH side, Air Fail Closed to RH side (Dresser)

- **Vane actuators** - Vane actuators are simple quarter-turn devices using a vane with an integral rotary output shaft to produce the torque (see Figure PA10). When air is applied to the actuator, it acts upon the area of the vane to produce force. As the distance from the centre of the vane to the axis of the output shaft is fixed, the torque output of a double acting vane actuator is constant (See Figure PA11). A coil (clock) spring can be mounted on top of the actuator to provide spring return.