

# Scotch Yoke Actuators

## White Paper

### *Better Design - Better Actuators*

Discussed are the benefits and the deficiencies of the basic scotch yoke actuator

.. and also how the QTRCO Flat Yoke design enjoys the benefits of the scotch yoke mechanism while eliminating all of the deficiencies.



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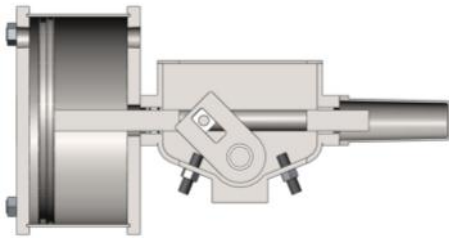
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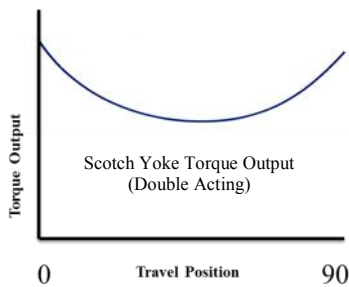
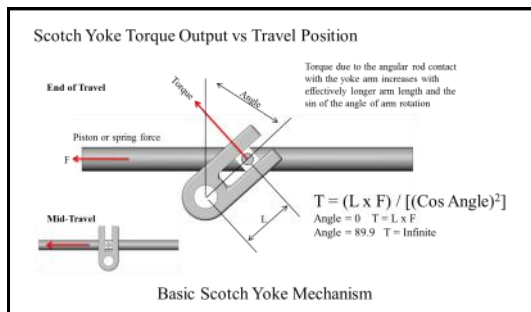
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**The Scotch Yoke Mechanism:**

The basic scotch yoke actuator consists of a slotted lever through which a rod passes while applying a force to the lever that is generated by pressure acting on a piston.

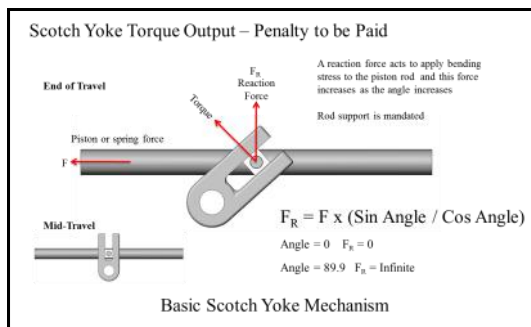


The lever is longer at the ends of stroke so that a given force results in more torque at the ends of travel than at the mid-travel positions. Additionally, the angular relationship between the input force and the lever also acts to increase the torque output.



**A Price to Pay:**

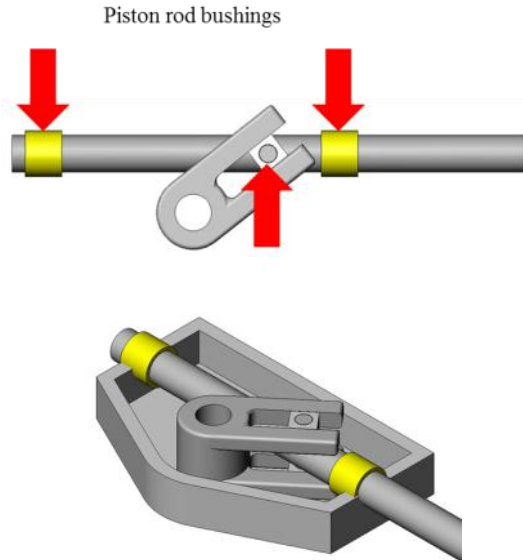
The increased end of stroke torque does not come without penalty which is a very high side loading force acting on the rod.



**Traditional Scotch Yoke Actuators:**

As demonstrated, the scotch yoke mechanism provides an ideal torque characteristic for many valve types and as the valve torque requirements increase, the scotch yoke becomes a relatively lower cost design to manufacture.

But because of the side loading forces applied to the rod, designers must contend with how best to provide rod support. Lacking an alternative means, designers (and those who have copied them) extend the rod through the actuator body to obtain support from bushings on both ends.



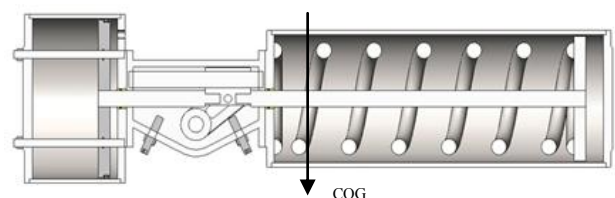
Better designers add a super structure to further support the rod.



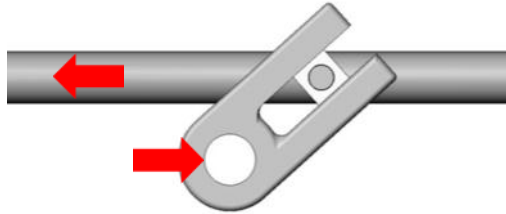
**Traditional Scotch Yoke Actuator - Design Compromises:**

Because the rod does extend through the body, force module location is limited by available space to one side of the shaft axis. The spring module is located on one end of the body and the piston module on the opposite end. The result is:

- **Weight imbalance** - The Center of Gravity is offset from the shaft axis and it continuously relocates as the actuator operates.

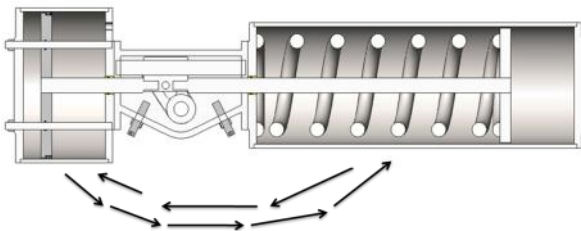


- **Force imbalance & High Friction Losses** - 100% of the piston and spring forces act upon the output shaft and the bushings that support the shaft. The shaft/bushing friction leads to wear and reduced output torque. For example, a 10,000# piston force is equaled by a 10,000# force acting on the shaft bushings.

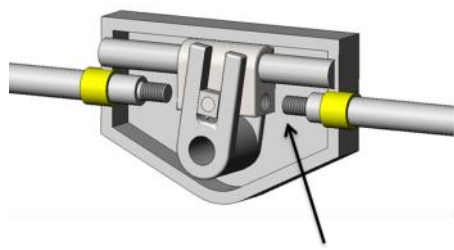


**Common Designer Induced Deficiencies:**

- **Proprietary Seals** - Most, but not all, designers apply pressure to the body side of the piston so that the springs are compressed toward the body. One reason is that this permits lighter, lower cost piston end tie rods while the spring forces act inward toward the body, lessening the strength requirements of the spring module attachment. The result however is the requirement that the rod be sealed between the piston and the body.
  - While the seals may be inexpensive for the manufacturer, they are often proprietary and for the user they normally are exorbitantly over-priced.
  - For seal replacement, additional costs include downtime, removal of the actuator from the valve and complete actuator disassembly by skilled personnel with in a well equipped facility.
- **Action Reversal:** Because the actuator bodies are normally one piece plus a cover, the cover side is not able to withstand the full torque output of the actuator. This limits mounting to the valve by only one side of the actuator.
  - ◊ Action reversal from fail closed to fail open therefore requires a complicated and time consuming interchange of the two force modules from one side of the body to the other.



- ◊ Often, force modules are attached to the body module via threaded rod, adding to the complexity of attachment.



Use care not to cross thread

**Design Commonality:**

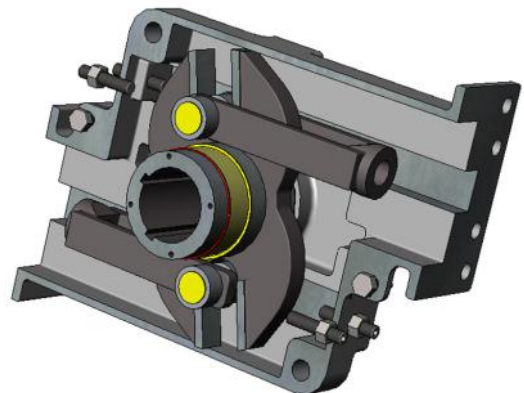
- Although Scotch Yoke actuators have been produced for many more than 50 years. Over this time, NEW designs may modify the attachment of the force modules or may change from applying pressure to the outer piston surface to the body side, but true change has not occurred.
  - ◊ Perhaps the forces applied to the rod simply prevented true change.
  - ◊ Perhaps an entirely new design approach is required.

## A Disruptive Technology

### The Ingenious QTRCO Flat Yoke™ Actuator

When designing the new QTRCO Flat Yoke actuator, we selected the scotch yoke mechanism as the basis, but rather than copy existing actuator designs, we began with a blank sheet and no pre-conceived limitations. We rationalized that:

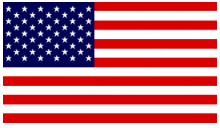
- If we could position identical force modules diagonally opposite one another on the body, there would be zero loads applied to the shaft bushings. Wear, friction and torque loss would be eliminated and the center of gravity would be on the shaft axis - a **Balanced Design**.
- But it is not possible to fit two force modules diagonally on the body if the rod is extended through the body as with existing designs.
- In response, our designers developed an innovative slotted body design that transfers all of the side loading forces to the body, allowing the rod to terminate at the lever slot.



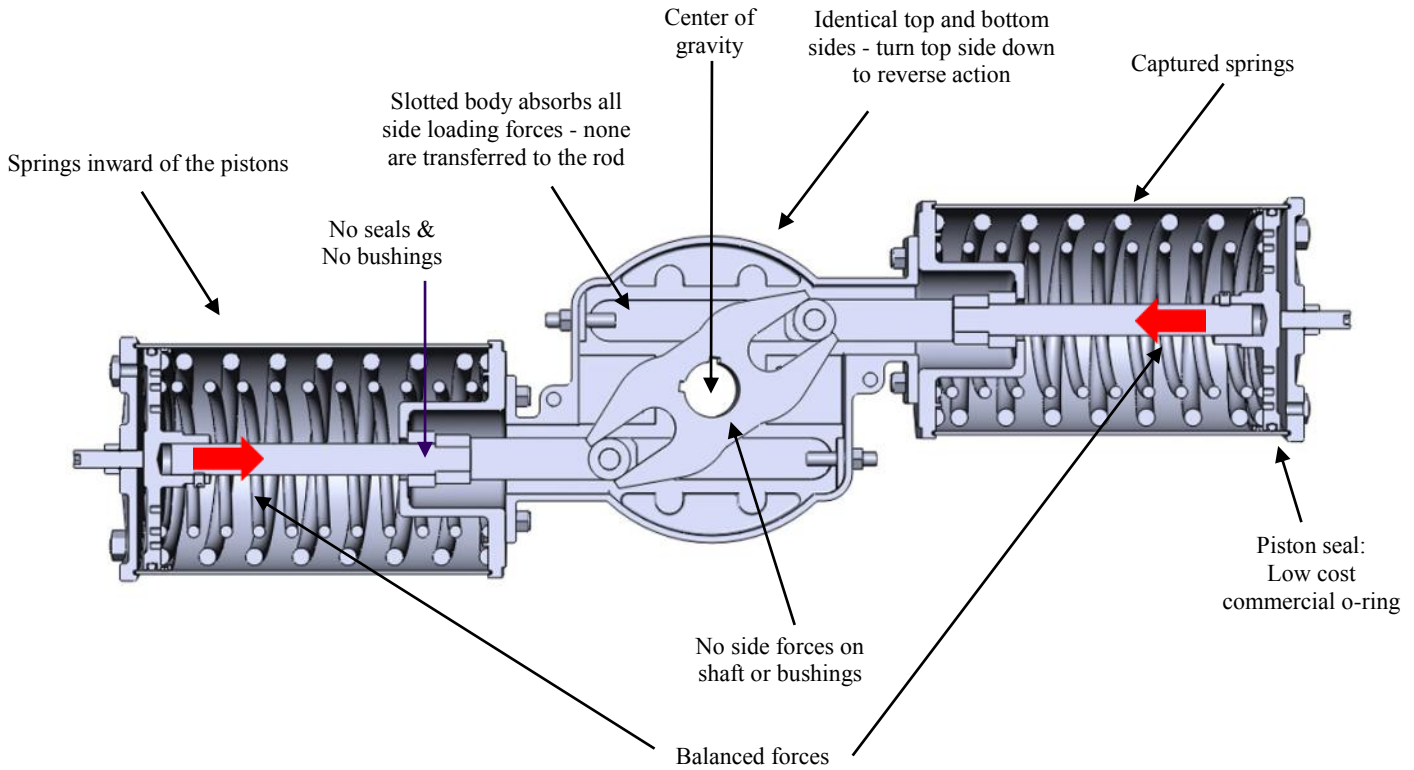
- **Result:**

Lighter, balanced weight	No loads on shaft bushings
No side loading of the piston rod	Greatly reduced friction
Smaller, lighter, shorter springs	Smaller pistons
Less wear	Increased torque output

Additionally, we rationalized that if a seal does not exist, it cannot fail. Therefore, as proven with our Rack & Gear™ actuators, we located the springs inward of the pistons, eliminating all dynamic seals except the piston o-rings - which, with the user in mind, are non-proprietary, commonly available, low cost o-rings.



MADE IN THE USA



- The spring inward design means that there is no need to remove the actuator from the valve for replacement of the low cost piston o-ring.
- ◊ Associated costs of seal replacement are also dramatically reduced. Eliminated are the high cost of heavy lifting equipment, numerous hours of labor, downtime and of course lost production revenue ...
- ◊ and by not having to remove the actuator from the valve, possible valve stem damage is prevented ...
- ◊ and accessories such as switchboxes and positioners will not require recalibration.
- ◊ A caveat - the low friction design will likely result in your not having to perform any maintenance, which is an even greater savings.
- ◊ Added bonus – Only the outer portion of the cylinder bore is traversed by the piston. If contaminants have scratched the cylinder bore, the cylinder can be turned end to end and re-installed with the original inward end now outward - essentially a no cost spare part.
- ◊ Finally, the top and bottom sides share identical geometries. Action reversal is achieved by simply turning the actuator top side down.



'On the valve' seal replacement

**THE RESULT** is an actuator of such capability that it carries an unparalleled 3 year warranty to provide, at no charge, replacement of any part that may fail or no charge repair if the user pays freight to and from QTRCO.