



Henry Pratt Company

401 S. Highland Avenue
Aurora, IL 60506
Phone: 630-844-4000
Fax: 630-844-4124
Email: marketing@henrypratt.com
Web: www.henrypratt.com

Manual Actuators for Use with Large Size Butterfly Valves

This paper will compare traveling nut actuators (both the scotch yoke [Figure A] and link lever [Figure B] designs) to worm gear actuators [Figure C] considering the operating needs of butterfly valves.

In general, the traveling nut actuator is inherently better suited to the normal quarter-turn operating requirements of a rubber seated butterfly valve, whereas the worm gear actuator is an adaptation of a design originally developed to fit the requirements of continuous, multiple turn or full-turn rotation. The following explains the importance of these differences as they relate to butterfly valves.

1. The ideal actuator for most normal butterfly valve operating requirements would turn the valve disc more slowly for each turn of the input shaft when the disc is near the closed position. This would provide the most precise flow control and reduce the possibility of water hammer. Ideally, it would also have its greatest mechanical advantage when the disc is at or near its closed position to provide the highest torque where it is typically most needed.

The traveling nut actuator was developed specifically for quarter turn valves. Its inherent design and mechanical advantages most closely fit the needs of a butterfly valve. In general, the peak torque requirements of a butterfly valve occur near its closed position. The peak torque output of a traveling nut actuator occurs at their same position [Figure D].

The worm gear actuator, on the other hand, does not have these characteristics. In fact, the worm gear actuator has a constant ratio of disc speed to input shaft rotation and a constant torque output through the entire movement of the butterfly valve disc [Figure D]. The worm gear actuator does not provide that extra boost of torque where the butterfly valve generally has its peak torque requirement, near the closed position.

2. In machining a worm gear set and the housing that supports the gears, a relatively large amount of clearance is required between the teeth of the two gears [Figure E] to prevent the gear set from binding. This relatively large clearance allows gear backlash, which can allow the butterfly valve disc to chatter or vibrate.

The traveling nut actuator does not require these large clearances, and it controls the valve disc more precisely to reduce disc vibration and chatter.

3. Inherent to the worm gear is the fact that fewer than three teeth are in contact at any given time [Figure E] and a relatively small area of line contact on each tooth must bear all of the stress. This creates very high contact pressures, which make the worm gear design dependent upon a constant source of "extreme pressure" lubricant to prevent galling and premature wear of the gear surfaces. The traveling nut design, in contrast, spreads the load over the surface of many threads on the input shaft. This results in lower contact pressures, which prevent galling and wear on the mating surfaces.
4. During overload conditions, the worm and worm gear are forced apart from each other by the tooth contact forces, which bear on the angled surfaces of the gear teeth [Figure E]. This separating force causes the shafts and housing to deflect, which allows the worm and worm gear to move away from one another. This causes the teeth to be overloaded near their tips, which further increases the tooth bending load. The combination of an overload and the resulting increase in bending load can cause the teeth to be overstressed at their base and fail.

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The traveling nut design, on the other hand, does not allow the mating threads to be forced away from each other because the traveling nut thread fully encompasses the input shaft thread within the strong body of the traveling nut. The traveling nut will not allow the threads to be spread apart from one another.

5. With the traveling nut design, the travel stops are typically a part of the input shaft assembly [Figure A&B]. If the traveling nut actuator is damaged by severe over torque at the stops, the damage is limited to the input shaft assembly; a threaded shaft which is relatively inexpensive and easy to replace. With the worm gear concept, the forces from over torque at the stops are transmitted through the gear set and into the stops which are mounted to the wall of the actuator housing [Figure C]. The worm gear design exposes more expensive, difficult to replace components to the forces of over torque at the stops. Damage may occur by breaking the worm or worm gear teeth, or by scoring their surfaces.
6. The AWWA standard for rubber seated butterfly valves, AWWA C-504 Section 3.8.5.5 entitled "Valve Actuators", under the paragraph entitled "Gearing", states that, "All gear actuators or traveling nut actuators will be self-locking..."

In the "Handbook of Practical Gear Design", by Darle W. Dudley, the author indicates that whether or not a worm gear set is self-locking depends on variables such as the lead angle of the gear set, the surface finish on the gears, the kind of lubrication, and the amount of lubrication where the unit is installed. In many applications of worm gear actuators with butterfly valves, these variables do not factor self-locking. In many circumstances, vibration generated by water flow modulation may allow a worm gear actuator to be rotated by the turbulent force of the flowing, which would cause the butterfly valve disc to lose its setting.

In contrast, the threaded spiral on a traveling nut actuator is of a much lower lead angle than that of the typical worm gear actuator. This makes the traveling nut actuator self-locking under all conditions.

7. The AWWA standard requires that actuators composed of worm gearing shall have bronze worm gears and hardened steel worms. Both of these requirements are inherently expensive, and neither is needed to produce a quality actuator with the traveling nut design.

In summary, the traveling nut actuator is much better suited to the normal operating requirements of a butterfly valve than is the worm gear actuator.

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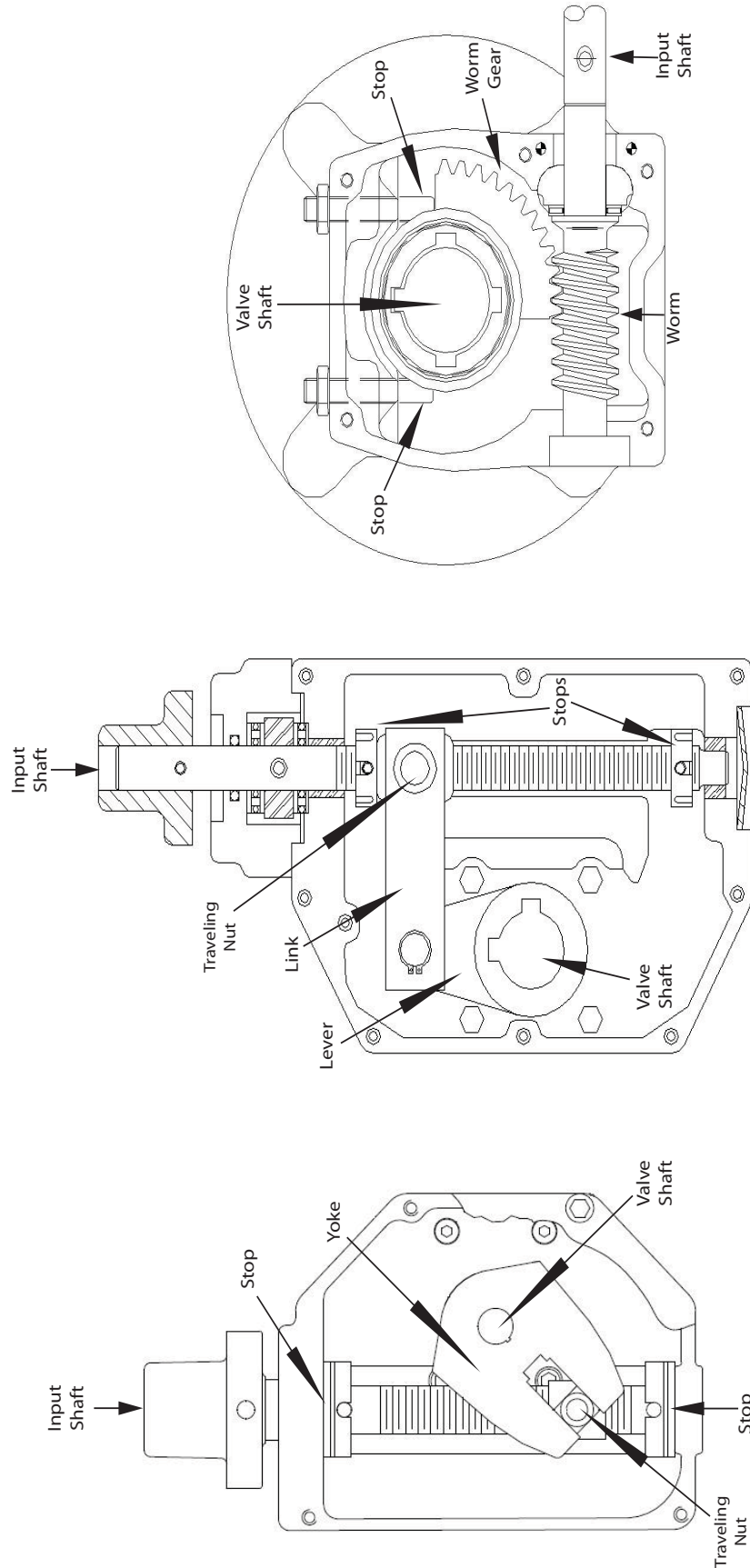


FIGURE C
Worm Gear Actuator

FIGURE B
Traveling Nut (Link Lever)
Actuator

FIGURE A
Traveling Nut (Scotch Yoke)
Actuator

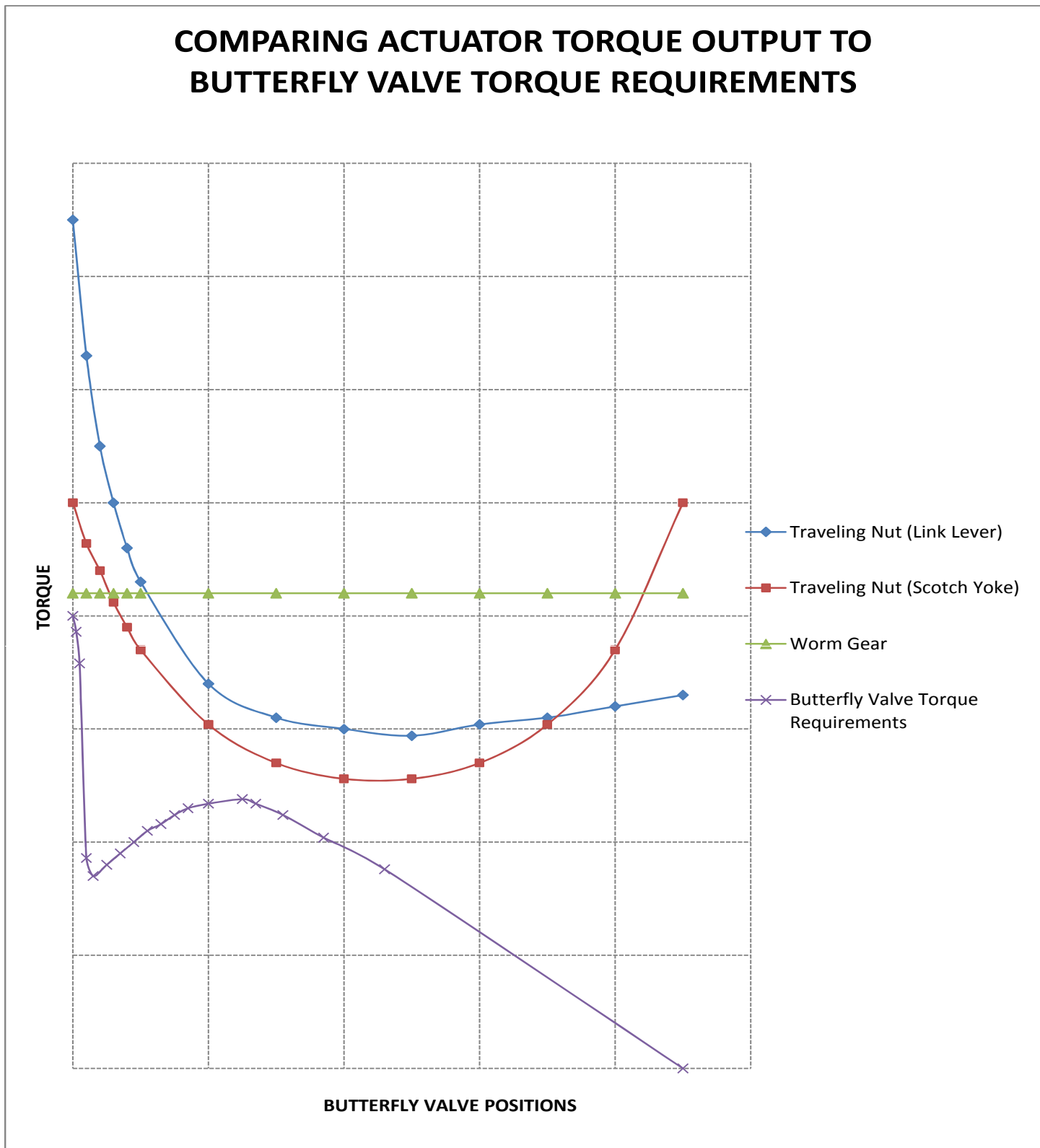
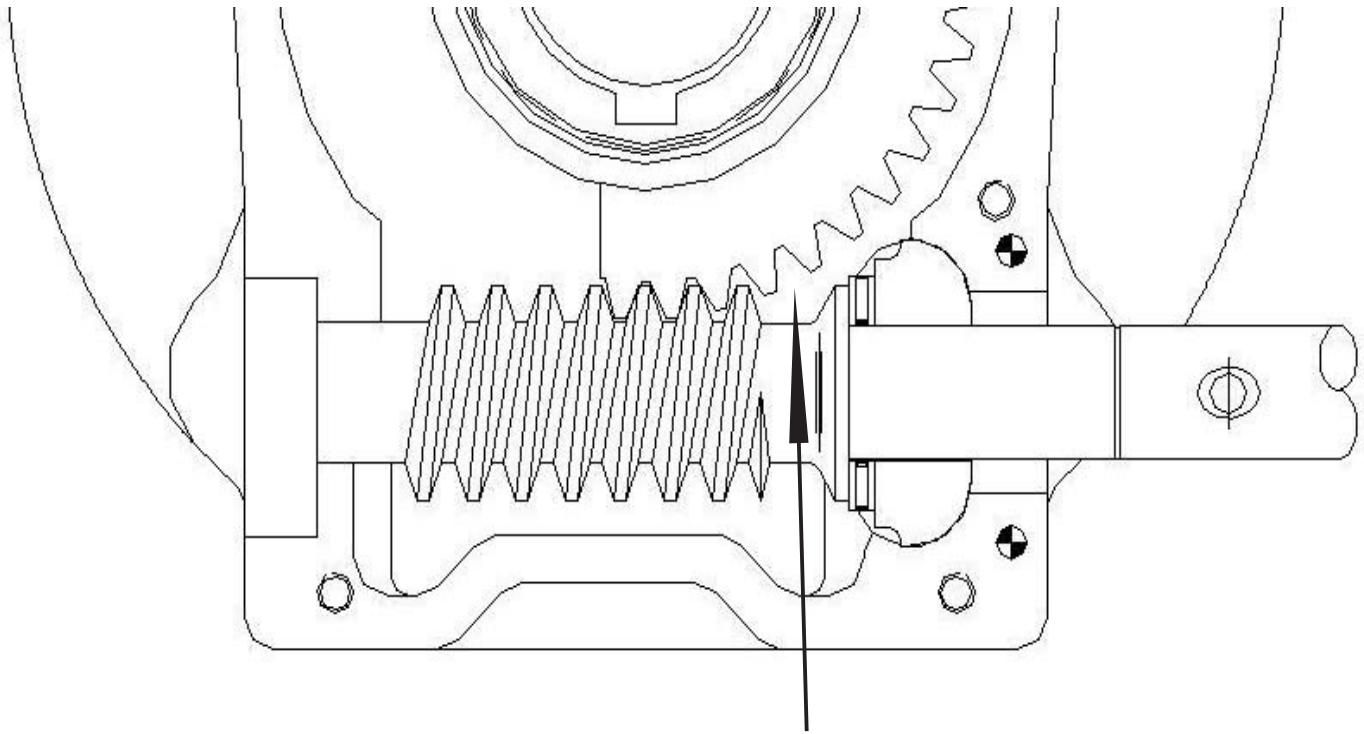


FIGURE D
Actuator Torque Requirements

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1. Constant ratio.
2. Relatively large clearance allows backlash.
3. Few teeth in contact.
4. Angeled surfaces force worm and gear apart. Cause teeth to be overloaded.

FIGURE E
Worm Gear Detail