A USER'S GUIDE

Using Valve Actuators As Predictive Maintenance Tools For MOVs

rotork

USING VALVE ACTUATORS AS PREDICTIVE MAINTENANCE TOOLS FOR MOVs

By: Chris Warnett
Rotork Controls, Inc.
675 Mile Crossing Boulevard
Rochester, NY 14624
716-328-1550
FAX: 716-328-5848
E-mail: info@rotork.com
Web site: http://www.rotork.com

INTRODUCTION

At the beginning of the twentieth century, before valve actuators were invented, virtually all valves were operated manually.

Experienced personnel could tell the condition of a valve's seat, stem, or packing simply by the feel of the operating handle as the valve was opened or closed.

For example, if the handle was harder to turn than the previous operation, then the operator could deduce that the stem was ready for regreasing. If the valve required more and more effort to provide shutoff, then the operator could deduce the condition of the seat.

Similarly, if the valve was easy to operate, then perhaps the seal packing needed adjustment.

Furthermore, because the operator was standing next to the valve in order to open or close it, a visual inspection of the valve easily could be made.

As a result, predictive maintenance, although not necessarily scientific, was achievable by this simple hands-on method.

However, with the advent of automation, the direct interface between the operating personnel and the valve has been eliminated.

EARLY VALVE ACTUATION

The first successful valve actuators had an inherent device, which sensed the amount of torque being delivered to the valve by the actuator. When it hit a preset limit, it would cause the actuator to shut off. This torque-sensing mechanism consisted of balancing the linear force of an actuator's worm shaft against a spring or springs. *(See Figure 1.)*

It was a simple step to fit an instrument such as a potentiometer or Linear Variable Differential Transformer (LVDT) to the end of the worm shaft of an actuator and get a continuous measurement of the actuator's torque output.

In the early 1980s, this was done extensively in the nuclear power industry where it was important to monitor the condition of certain critical nuclear valves.

These devices were fitted to valve actuators so that the torque demand could be recorded and plotted against the position of the valve. Although these devices were expensive to fit and operate, they were justified by the extreme safety requirements needed for operating nuclear power plants.

When critical safety valves were first installed, a “footprint” torque profile of the valve was taken. Subsequent torque position readings on these valves were compared to the original “footprint.” Problems with the valve or actuator then could be identified by comparing the data.

MAJOR BREAKTHROUGH

In the mid-1980s, Rotork introduced a robust digital communication system to the marketplace – PakScan – which enabled large numbers of actuators to be linked together using a single, shielded, twisted pair of wires.

The PakScan system utilizes a master station as a loop management device which talks via the twisted shielded pair to PakScan field units in each actuator.

Because the communication between the master station and the actuator is digital, the number of wires no longer restricts the amount of information that can be gathered. The master station manages the loop by constantly scanning each actuator and detecting any changes in status.

It stores the information and relays it back to a host DCS or PLC on demand. The master station communicates to the host using standard Modbus RTU protocol.

Figure 1. Torque-sensing mechanism used in electric actuators.

The development of the Pakscan system was an important step in the control of valve actuators, because a large amount of data could be collected without the prohibitive cost of large numbers of copper wires to retrieve information.

When this equipment was linked to a Rotork IQ electric actuator, then true valve diagnostic capability was introduced.

The breakthrough of the IQ enabled continuous torque and position information to be gathered by the actuator itself.

When the data was transmitted via a Rotork PakScan two-wire communication system to PakVision software, then continuous monitoring of torque and position allowed for comparison between the footprint torque characteristic of the valve during installation and subsequent torque profiles.

The original PakVision software (and the latest version, which is called InVision™ software) is a Rotork Man/Machine Interface (MMI) for the PakScan system.

PakVision and InVision software allow operators not only to control field devices, but also monitor their status on configurable screens on a standard IBM-type PC.

PakVision and InVision

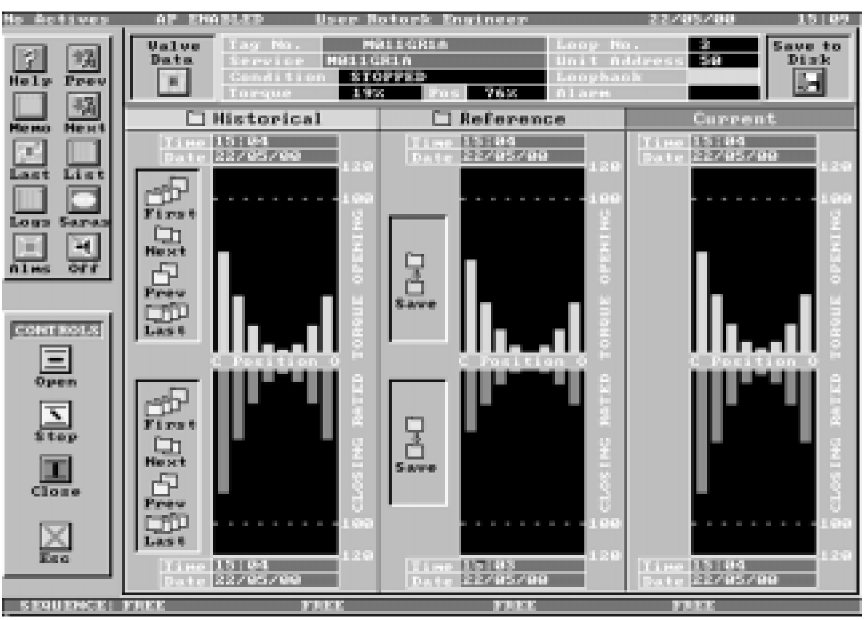


Figure 2. Rotork PakVision and InVision software take data from the IQ actuator via the PakScan system and display it as easy-to-read bargraphs.

software can also keep comprehensive logs of status changes, alarms, and operator actions. This software is often used as a backup for the main host MMI software. It's also valuable to maintenance personnel as an off-line recordkeeping and device monitoring tool.

With these tools, motor operated valve end users are able to monitor the torque demands of their valves and can view sudden changes in torque demand or trends in demand over a period of time. *(See Figure 2.)*

Another development associated with the IQ actuator is that it enabled data to be stored in the actuator itself utilizing a data logger card.

The data logger card stores the condition of 32 discreet signals associated with actuator components, including monitoring position switches, local/remote selectors, "Stop" button, and other data as well as torque and position information.

By downloading this information into a hand-held computer, it can be removed offsite for detailed analysis. *(See photo below.)*

LATEST ADVANCE

The innovations of the early 1990s have now been enhanced and modified to

You can use the Rotork data logger to download vital information for offsite analysis.

provide highly accurate information and analysis of motor operated valves.

The latest Rotork IQ features a built-in data logger, which records information from an advanced and highly accurate torque-sensing mechanism, which constantly monitors the actuator's torque output by accurately measuring the worm shaft-force reaction electronically.

This information, together with position data and the other discreet component data, are stored in the actuator for future analysis.

When a motor operated valve is first commissioned in a plant, pipeline, or other facility, the initial torque demand is recorded in the data-logging chip as the "footprint."

This serves as a reference point for future torque readings so comparisons can be made and the condition of the valve diagnosed. *(See Figure 3.)*

The data from the data logger can be collected locally utilizing a PC with an infrared link connected to the actuator indicator window. The PC can run its diagnostic analysis utilizing IQ-Insight software.

Also, actuators fitted with PakScan can transmit data

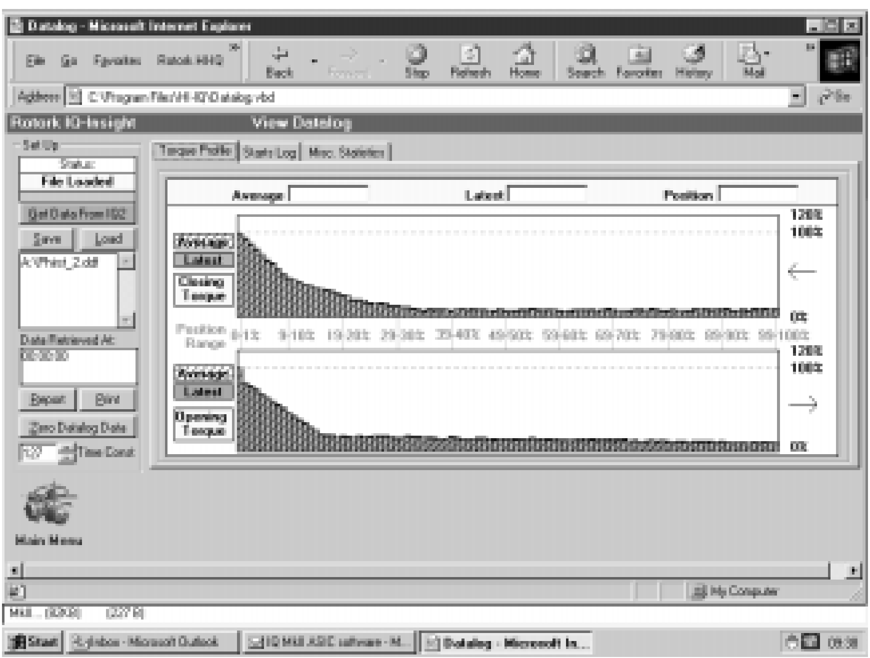


Figure 3. Rotork IQ actuators can gather continuous torque and positioning information. Above is an IQ torque profile using IQ-Insight™ software.

directly via a PakScan master station to either the remote host controller, PLC, DCS, or to a PC running diagnostic software, such as InVision.

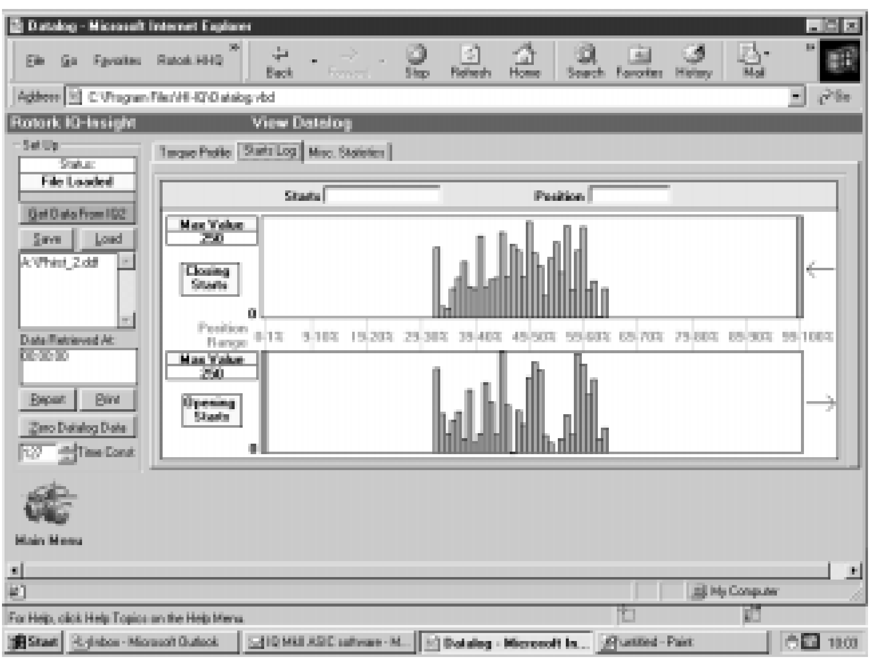
HOW TO USE THE DATA

The question is: What does one do with the data once it is collected?

Usually, the most useful data relates to torque, so Rotork has concentrated on this. The IQ-Insight data also allows analysis of frequency of operation and other parameters, so contactor wear or stem wear can be explained by studying the operation record of IQ-Insight or Pakvision software files.

Let's examine the different valve torque elements. These can be broken down into seven main components:

- **Valve Seal or Packing Friction**
- **Valve Shaft Bearing Friction**
- **Closure Element on Seat Friction**
- **Closure Element In-Travel Friction**
- **Hydrodynamic Force on Closure Element In-Travel**
- **Stem Piston Effect**
- **Valve Stem Thread Friction.**



The above image is a view of a Rotork IQ-Insight screen showing frequency of operation data.

Most of these elements are present in all types of valves, but in varying degrees of magnitude.

For example, the closure element travel friction in a butterfly valve is negligible, whereas in a lubricated plug valve, it is more significant.

Valve actuators are designed to limit their torque to a preset level (torque switch setting) in the closing direction. An increase in torque above this level will stop the actuator.

In the opening direction, the torque switch is bypassed for the initial unseating operation. The resulting torque profile is therefore useful in analyzing the valve condition.

PROFILES OF DIFFERENT VALVE TYPES

Let's look at the different types of valves and how these different elements build up the torque profile of the valve.

Wedge Gate Valve

The significant torque requirements for opening or closing a wedge gate valve occur during the final travel going closed and the initial travel going open.

During the remaining portion, the torque demand is made up mainly of packing friction and thread friction of the Acme-threaded shaft.

As the valve seats, the hydrostatic force on the closure element (the disc), increases the

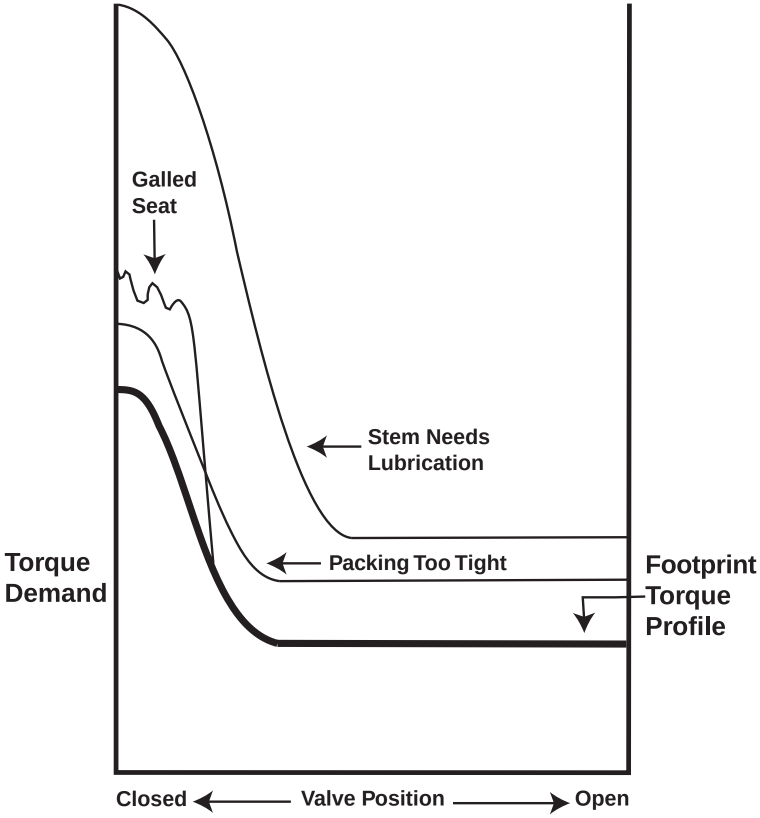
TYPICAL CHARACTERISTICS OF A WEDGE GATE VALVE
Valve Seal or Packing Friction – function of stem diameter.
Valve Shaft Bearing Friction – negligible.
Closure Element on Seat Friction – wedge effect.
Closure Element In-Travel Friction – negligible.
Hydrodynamic Force on Closure Element In-Travel – negligible.
Stem Piston Effect – function of pressure; negligible below 1,000 psi.
Valve Stem Thread Friction – function of thread form and lubrication.

seating friction, and finally the wedging effect of the disc in the seat causes a rapid increase in torque demand until seating is affected.

Similarly, when unseating the valve, the disc has to be unwedged and the hydrostatic force of the differential pressure across the valve has to be overcome as the valve is opened.

Once the valve is cracked open and the differential pressure has dissipated, then the torque

The photo above shows automated wedge gate valves.



Opening Torque Characteristics of a Typical Wedge Gate Valve

(FIGURE 4)

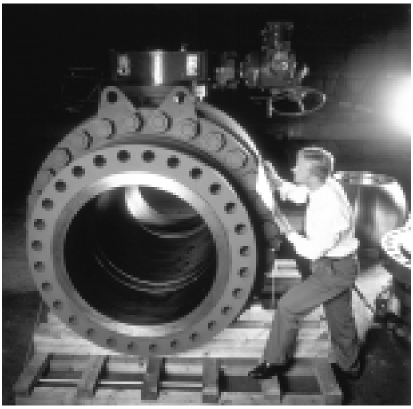
demand drops off significantly. In Figure 4, you can see the total torque profile of the valve. Should, for example, the valve stem packing be overtightened, then an immediate increase in torque profile would be recorded. Should the lubrication on the thread deteriorate over time, then you would see an incremental increase in overall torque per the diagram.

Alternatively, should the valve seat become galled or deteriorate, then you would see an increase in the unseating torque required.

Ball Valve

The main contributors of torque to a ball valve are:

1. The shaft bearing friction. This could include the friction



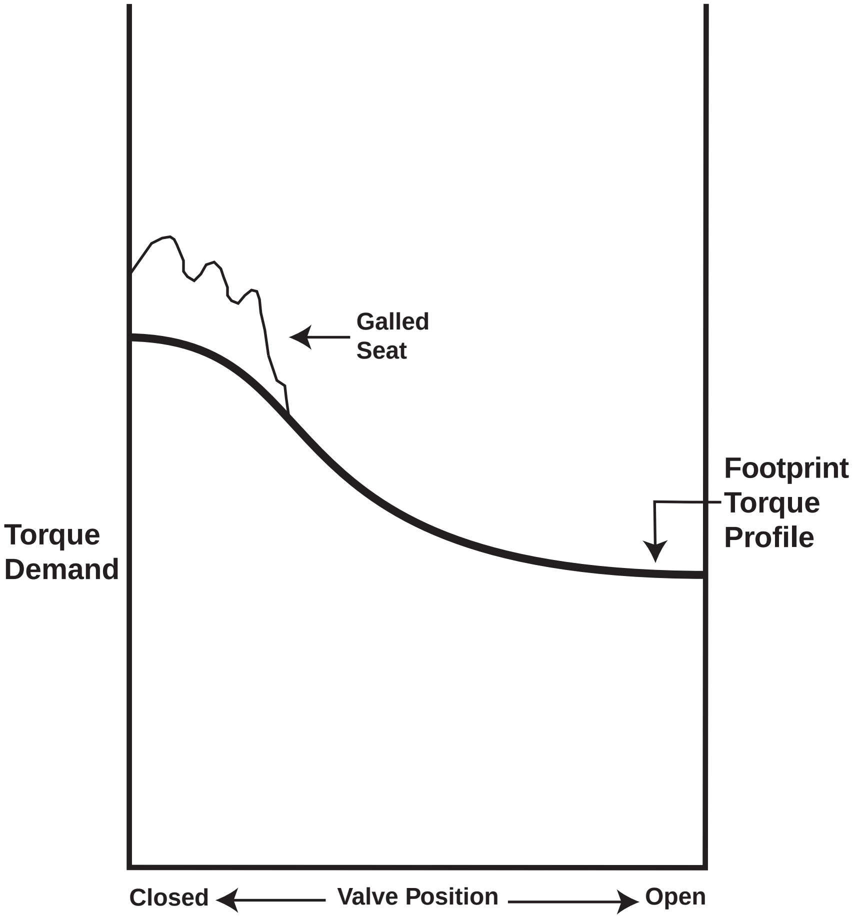
Example of a ball valve.

of any 'o' ring seals which are frequently used to seal ball valve shafts.

2. The ball (closure element) on seat friction during closing and opening.

As can be seen from the diagram *(See Figure 5)*, shaft bearing friction is usually a constant as is the ball on seat

TYPICAL CHARACTERISTICS OF A BALL VALVE
Valve Seal or Packing Friction – constant.
Valve Shaft Bearing Friction – function of differential pressure.
Closure Element on Seat Friction – function of differential pressure.
Closure Element In-Travel Friction – constant.
Hydrodynamic Force on Closure Element In-Travel – negligible.
Stem Piston Effect – none.
Valve Stem Thread Friction – none.



Opening Torque Characteristics of a Typical Ball Valve

(FIGURE 5)

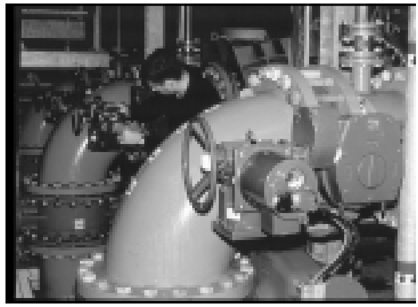
friction during travel, but at the closed position, just prior to closing and during opening, the ball on seat friction is increased significantly. This is due to the differential pressure acting on the ball in the floating ball design, or on the seat in the trunion design, forcing the ball and seat together to provide sealing.

Should the ball or the seat become scored or pitted, then the torque demand at the closed position would increase.

Butterfly Valve

The main elements of torque in a butterfly valve are:

1. Bearing friction, together with valve shaft seal friction, which is typically an ‘o’ ring and therefore constant.



Pictured above are Rotork IQ actuators on butterfly valves.

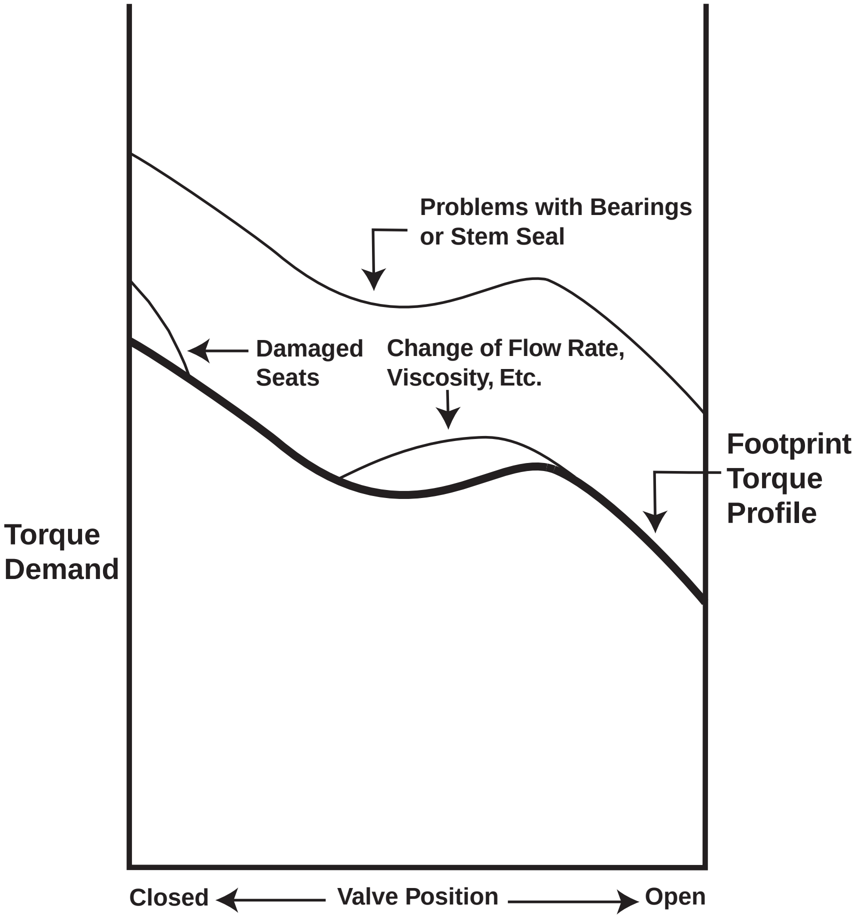
2. Closure element on seat friction; in other words, the disc on seat friction.

3. Hydrodynamic forces on the closure element in travel.

Because the disc of a butterfly valve is directly in the middle of the fluid stream, then dynamic forces could act on the disc to exert a backdrive torque on the actuator.

Problems with the bearings on

TYPICAL CHARACTERISTICS OF A BUTTERFLY VALVE
Valve Seal or Packing Friction – constant.
Valve Shaft Bearing Friction – constant.
Closure Element on Seat Friction – high at closure.
Closure Element In-Travel Friction – none.
Hydrodynamic Force on Closure Element In-Travel – mid-travel.
Stem Piston Effect – none (not applicable).
Valve Stem Thread Friction – none (not applicable).



Opening Torque Characteristics of a Typical Butterfly Valve

(FIGURE 6)

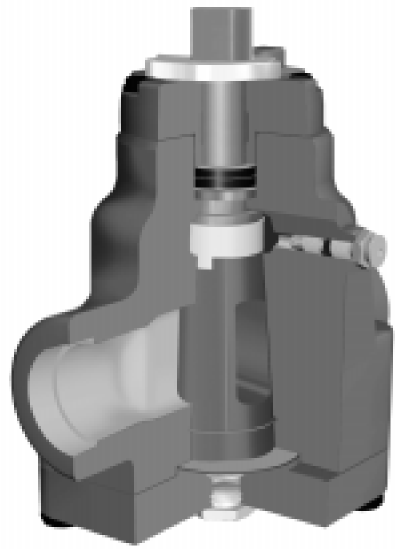
a butterfly valve show up as an increase in torque across the entire stroke of the valve.

Damaged seats or damaged discs affect the closing and opening torque over the first few degrees of valve travel.

Changes in flow rates, fluid viscosity, temperature, etc. affect the dynamic torque demand in the middle of the stroke; however, this would not necessarily be an indicator of a problem with the valve itself.

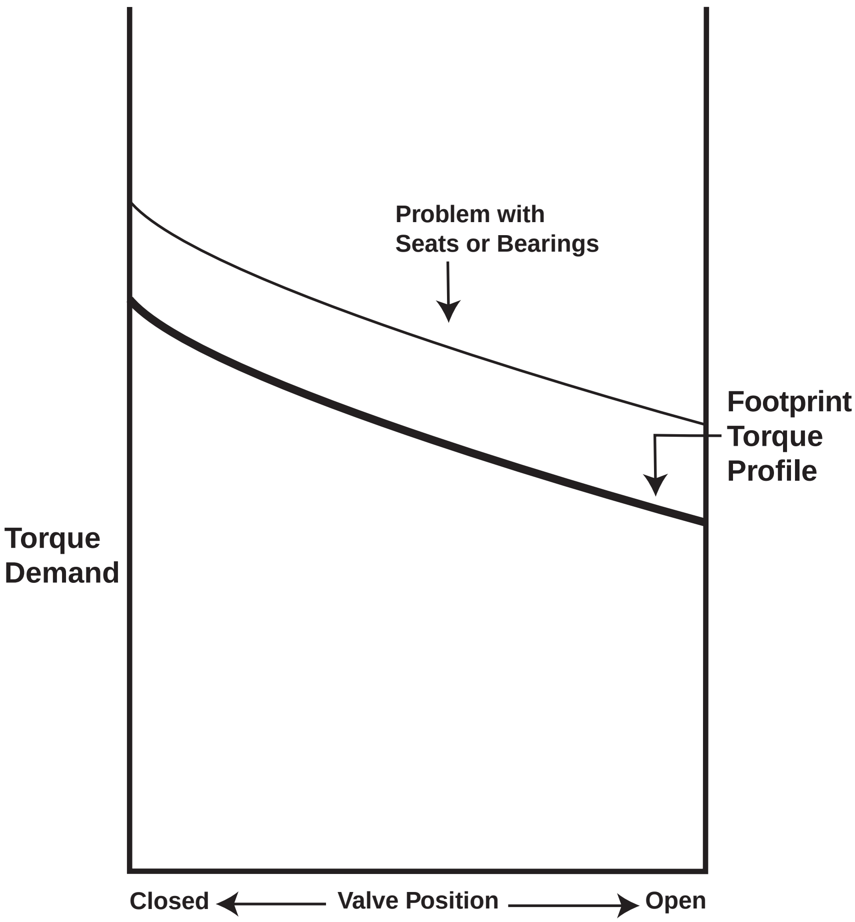
Lubricated Plug Valve

The torque elements in a lubricated plug valve are more constant than other valves due to the relatively high friction between the closure element – the plug, and the valve.



Pictured above is a lubricated plug valve. The illustration was provided courtesy of Nordstrom Valves, Inc.

TYPICAL CHARACTERISTICS OF A LUBRICATED PLUG VALVE
Valve Seal or Packing Friction – constant.
Valve Shaft Bearing Friction – constant.
Closure Element on Seat Friction – rises somewhat with differential pressure.
Closure Element In-Travel Friction – constant.
Hydrodynamic Force on Closure Element In-Travel – none (not applicable).
Stem Piston Effect – none (not applicable).
Valve Stem Thread Friction – none (not applicable).



Opening Torque Characteristics
of a Typical Lubricated Plug Valve

(FIGURE 7)

Bearing friction and closure element on seat friction are relatively constant throughout the stroke. Hydrostatic forces during closing and the first few degrees of opening would increase the torque demand. A typical lubricated plug valve torque demand is represented in *Figure 7*.

Problems with the bearings or the seats would reflect uniform torque increase across the stroke.

Resilient Seated Plug Valve

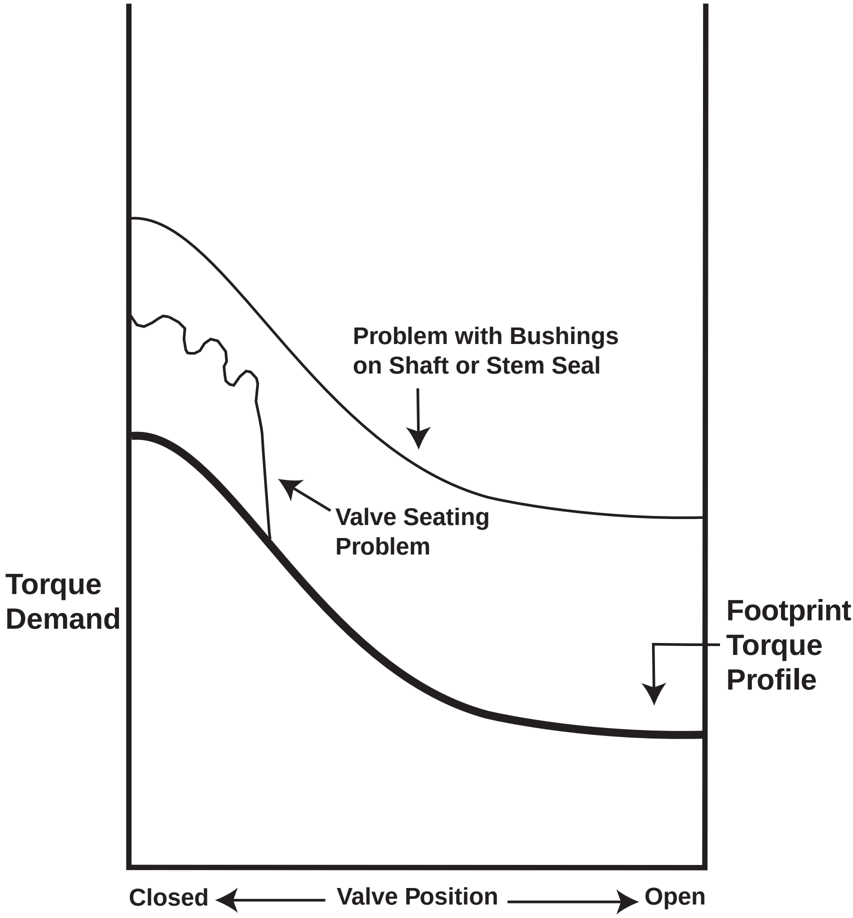
The torque characteristic of a resilient seated plug valve reflects a relatively high seating and unseating torque to constant bearing and seal friction throughout the stroke.

As the closure element does not touch the body of the valve or the seat during travel, there is no closure element travel friction, similar to a butterfly valve. A typical torque curve is represented in *Figure 8*.

Problems with the valve seating would be reflected in the torque demand during closing

Pictured above is a DeZurik Rubber Lined Eccentric Plug Valve.

TYPICAL CHARACTERISTICS OF A RESILIENT SEATED PLUG VALVE
Valve Seal or Packing Friction – constant.
Valve Shaft Bearing Friction – constant.
Closure Element on Seat Friction – high at closure.
Closure Element In-Travel Friction – none.
Hydrodynamic Force on Closure Element In-Travel – low.
Stem Piston Effect – none (not applicable).
Valve Stem Thread Friction – none (not applicable).



Opening Torque Characteristics of a Typical Resilient Seated Plug Valve

(FIGURE 8)

and opening. A problematic bushing on the shaft would manifest itself as a constant torque increase throughout the stroke as indicated in *Figure 8*.

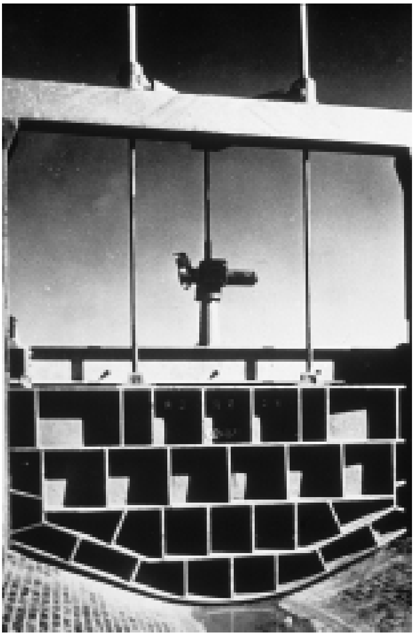
Sluice Gate

In the closed position, the full head of fluid is acting against the gate.

As the gate opens, the head decreases relatively gradually and in proportion to the position of the gate.

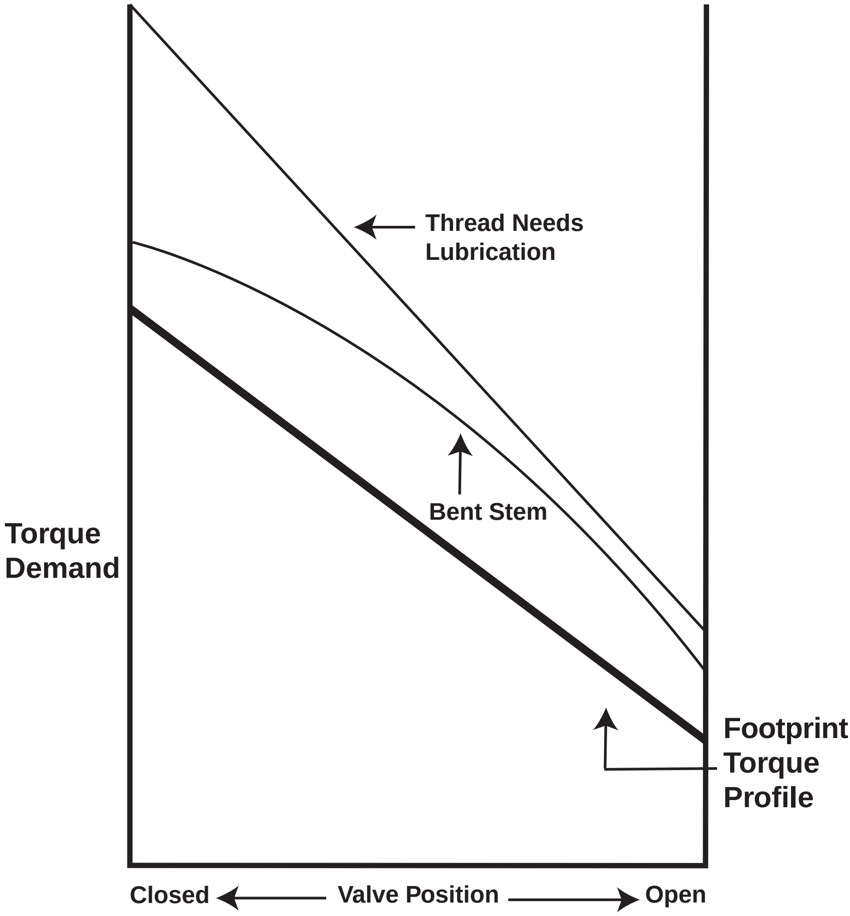
Because sluice gates are exposed to the elements, stem lubrication should be a regular maintenance item.

This can be easily monitored as a gradual increase in torque across the entire open stroke.



Above is a Rotork IQ actuator operating a sluice gate. To assure optimum operation, sluice gate stems need to be lubricated regularly.

TYPICAL CHARACTERISTICS OF A SLUICE GATE
Valve Seal or Packing Friction – constant.
Valve Shaft Bearing Friction – constant.
Closure Element on Seat Friction – wedge effect.
Closure Element In-Travel Friction – guide friction against closure element (gate).
Hydrodynamic Force on Closure Element In-Travel – none, but hydrostatic force on gate throughout stroke.
Stem Piston Effect – none.
Valve Stem Thread Friction – function of thread form and lubrication.



Opening Torque Characteristics of a Typical Sluice Gate

(FIGURE 9)

EXAMPLES OF PREDICTIVE MAINTENANCE BENEFITS

Below are a few examples of the benefits of predictive maintenance in various applications.

Wastewater Industry

Most wastewater plants utilize sluice gates to control flow through their facilities.

The sluice gates often are mounted outdoors with the stems exposed to the elements. This means that any lubrication that may be utilized on the stems frequently is subjected to the drying effects of the sun, the erosive effects of dirt and water, as well as contamination from airborne particulate.

As the sluice gates are operated and the stems pass through the drive nut of the actuator, the drive nut experiences a certain amount of wear. This is directly proportional to the torque demand of the sluice gate.

When the sluice gate is initially installed and the stem is well lubricated, the minimum level of torque is needed for operation. After a period of six months, assuming there has been no additional attention paid to the stem of the sluice gate, the torque demand will increase as the lubrication deteriorates.

Rotork IQ actuators are used extensively throughout wastewater treatment facilities.

A further six months would show yet a further increase in torque demand. If no preventive maintenance is performed on the stem, then eventually the torque demand will reach a point where the efficiency of the drive is so low that the drive nut in the actuator could experience rapid and catastrophic wear.

This can be prevented by monitoring the increase in torque demand of the sluice gate over time such that the rate of increase in torque demand can be quantified, and the optimum point for stem lubrication predicted.

This predictive maintenance can not only increase the life of the sluice gate, but also eliminate the potential for catastrophic failures, which can occur when conditions become so bad that the drive stem of the actuator fails allowing the sluice gate to drop into its seat.

Power Industry

In power plants, there are many high temperature lines containing steam or water.

Often, these lines are controlled by gate or globe valves to isolate flow during startup and shutdown of a plant.

Plants that are not on a baseload may find that they are cycling twice a day. Under these circumstances, when the valve stem is withdrawn from the valve, it cools to the ambient temperature outside of the pipeline insulation, while the valve remains at the temperature of the fluid media.

However, on closing, the valve stem is now inside the valve and absorbs residual heat, increasing in temperature until it reaches equilibrium with the valve body.

This means there is the potential for the valve stem to expand inside of the valve body, generating a thrust over and above that delivered by the actuator to provide tight shutoff.

In these circumstances, valve stems can take a permanent offset or valve seats can become galled.

If the valve stem has been slightly bent, the situation can be detected by the torque profile of the actuator from a localized high spot in the torque chart somewhere in the mid-portion of the stroke. As the plant continues to cycle, the offset of the stem would increase as the greater the offset, the lower the resistance to bending. This would result in greater and greater torque demand in the mid-stroke area as the valve stems takes a greater and greater offset.

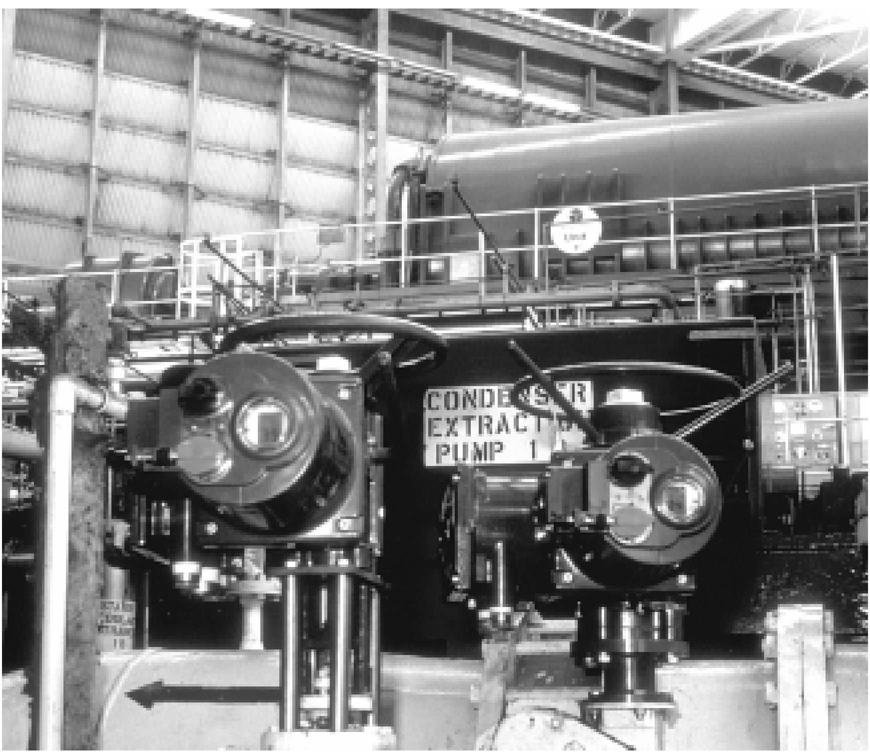
This increasing torque trend in mid-stroke can be detected utilizing torque profiling methods.

Given sufficient time to catch the failure mechanism, the valve stem can be removed and straightened, so the cost of replacing the valve stem can be avoided. In these circumstances, where differential thermal expansion is the root cause of the problem, a more resilient mounting can be provided to avoid repetition of the failure mechanism.

Similarly, if the seats are galled in the valve, then the unseating torque will increase. As the valve continues to cycle, the galling will get progressively worse, displaying an increased torque demand in the unseating torque curve.

Refining Industry

One of the most arduous duties for a valve is coker



The power industry has found Rotork IQ actuators to be reliable.

service in an oil refinery.

The coking process is a batch process whereby first one coker is in process while an adjacent coker is being emptied. Constant cycling is required of the coker valves every few hours.

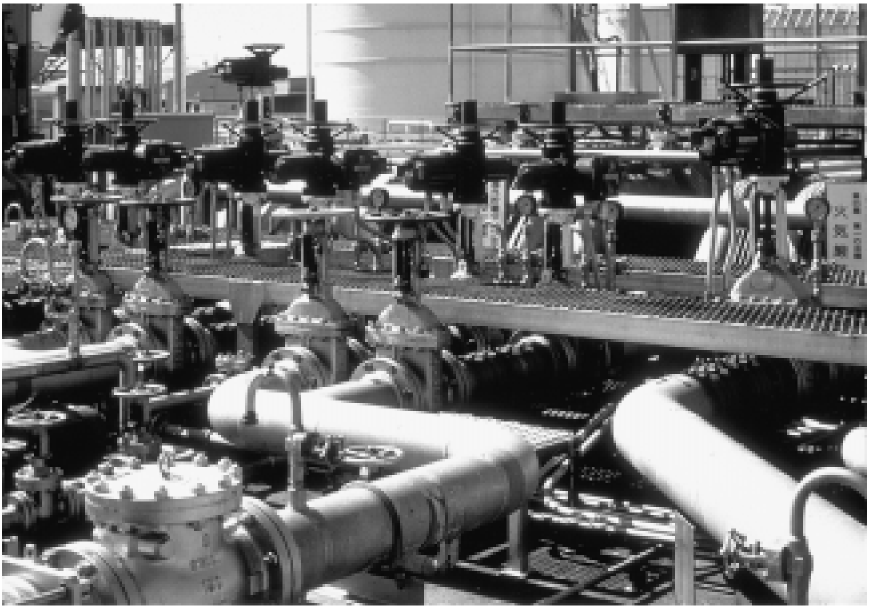
The coke media itself is extremely tough on the valve and tends to stick to the seats and other parts of the valve.

Frequently, heavy-duty ball or plug valves are used in this service. Coker operators monitor these valves carefully to anticipate maintenance problems.

Because they are a high-maintenance item, downtime is inevitable; however, if problems can be anticipated, then the impact can be minimized.

Not only can torque profiling on coker valves indicate coke buildup on the valve, but also the rate of buildup and the deterioration of the valve's effectiveness. By monitoring the increase in torque at the ends of stroke and over the stroke itself (depending on the valve), quarter-turn valves can be maintained at exactly the right interval.

This can reduce unplanned downtime and allows replacement equipment to be preordered so last-minute rushes can be avoided.



Rotork IQ actuators in a refinery industry application.

Comprehensive Web Site

To find out more about Rotork valve actuators and applications, we invite you to visit our Web site at **www.rotork.com.**

The site offers a comprehensive overview of actuator applications, comments by users of Rotork actuators, an overview of Rotork products and specifications, worldwide sales addresses and contacts, and much more.

Also, from the Web site, you can order free CDs that provide in-depth sizing and specification information about Rotork electric and fluid power actuators.

For More Information

For more information about torque profiling and predictive maintenance, contact:

Mr. Chris Warnett
Rotork Controls, Inc.
675 Mile Crossing Boulevard
Rochester, NY 14624 USA
Telephone: 716-328-1550
Fax: 716-328-5848
Email: info@rotork.com

Rotork is 9001 certified and has registered approval by Foundation Fieldbus.