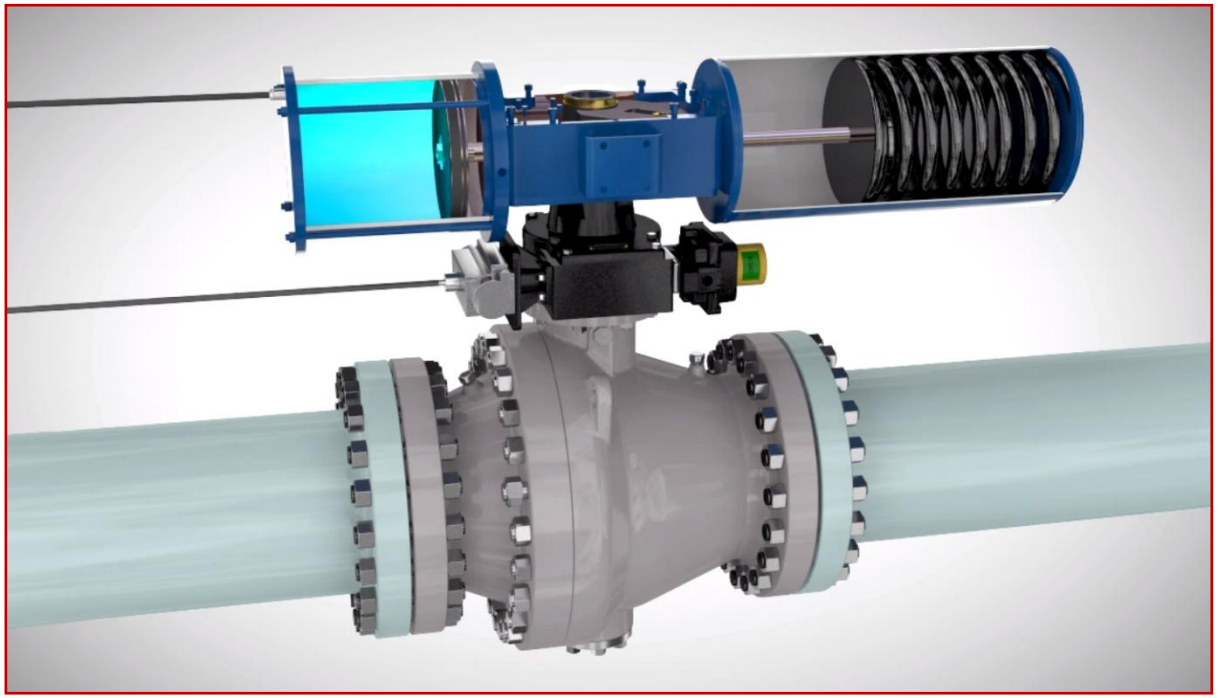


Reconsidering Mechanical Devices for Partial Stroke Valve Testing

Mike Mitchell
Cameron Flow Control / DYNATORQUE

Mary Kay O'Connor Process Safety Center International Symposium : October 26-27, 2010

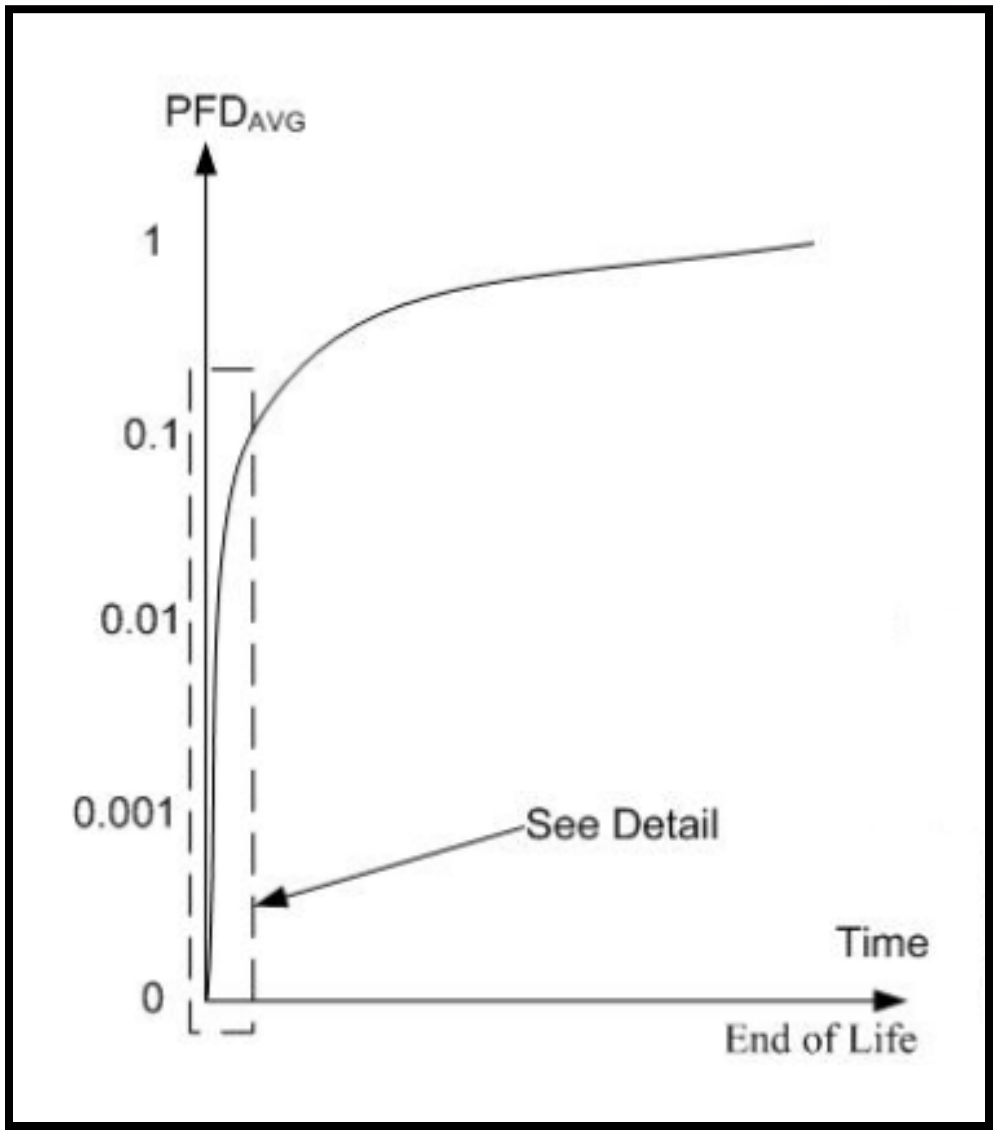
Mechanical PST: Introduction

PST does not replace Full Stroke Test

Lower the average probability of failure on demand (PFD_{AVG}) between established full stroke test intervals

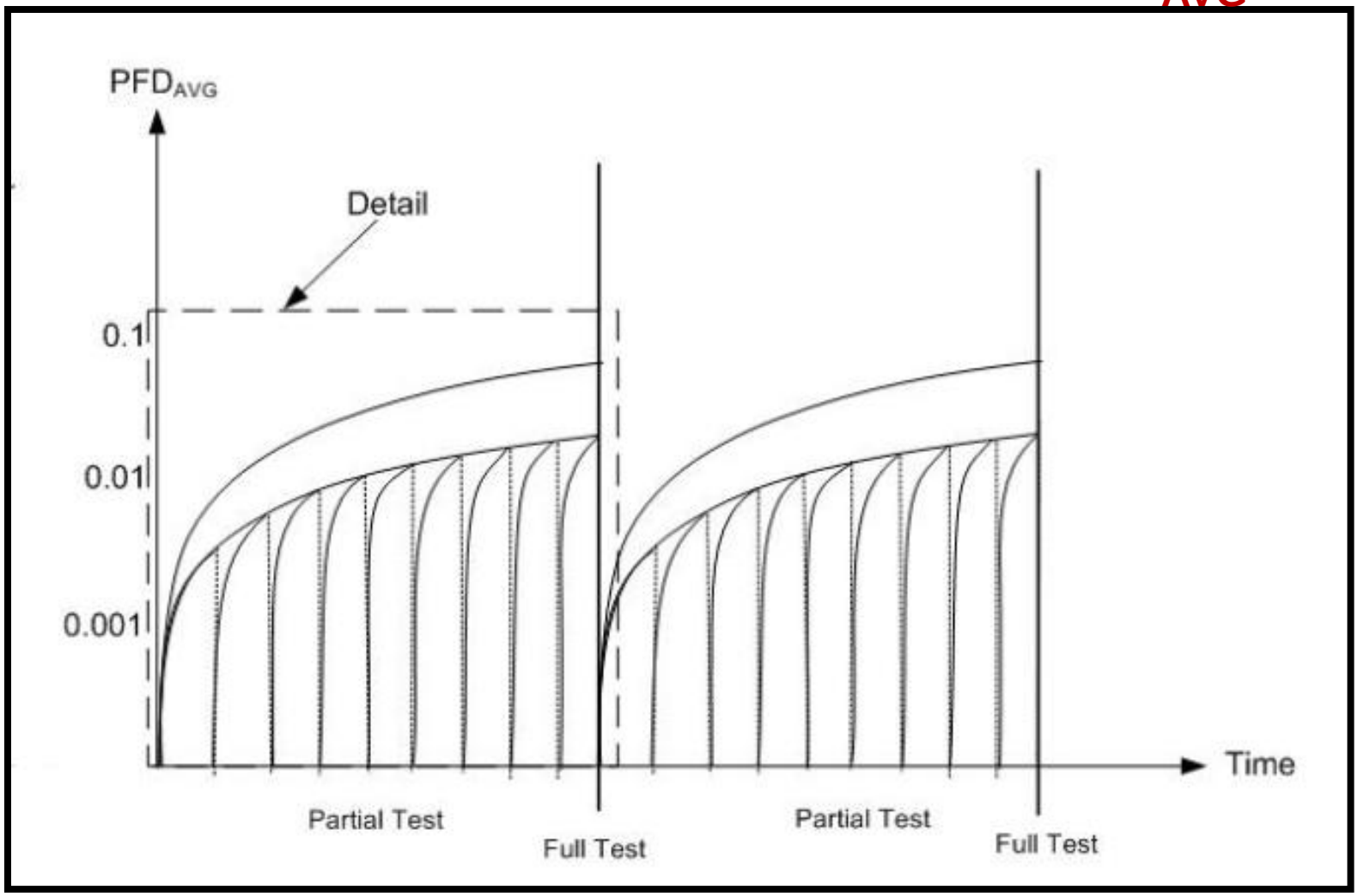
- or -

Increase time between full stroke test intervals while maintaining or lowering the PFD_{AVG} .



PFD_{AVG} increases with time

Partial and Full Stroke tests decrease PFD_{AVG}



Safety Integrity Levels (SIL) reflect relative levels of risk reduction

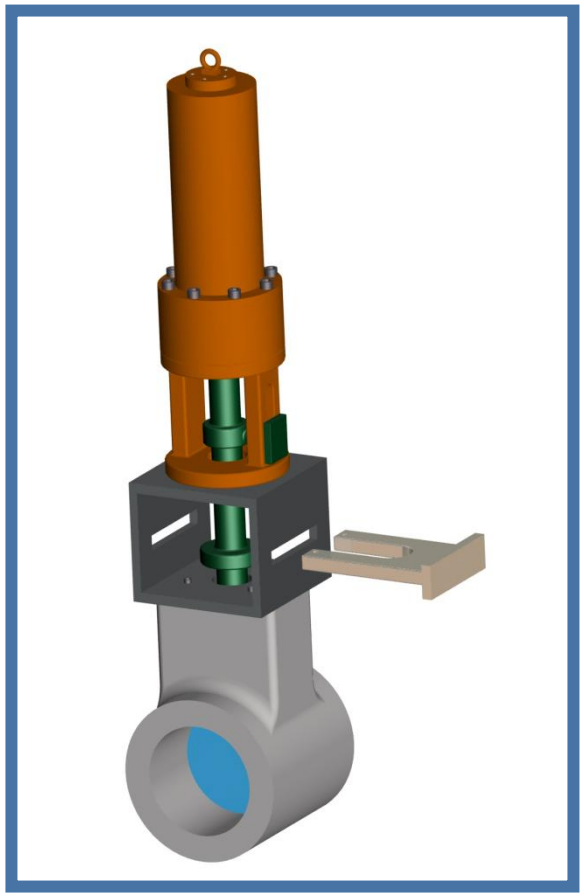
Table 3 – Safety integrity levels: probability of failure on demand

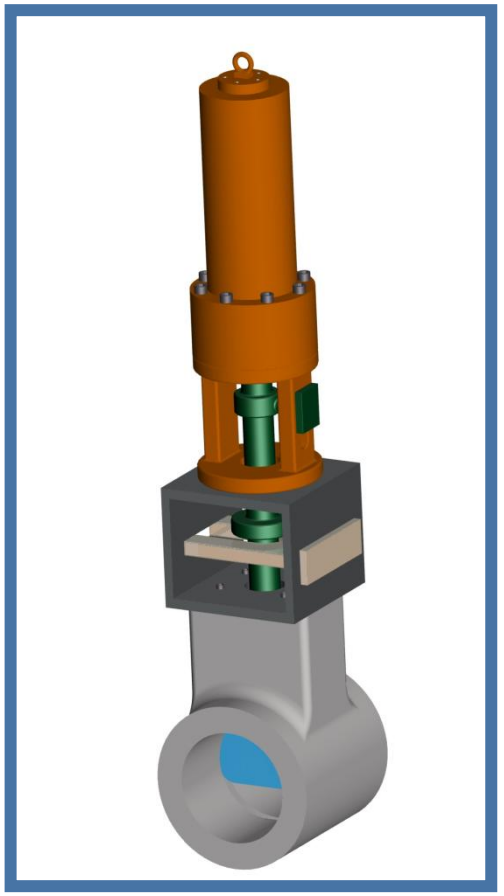
DEMAND MODE OF OPERATION		
Safety Integrity Level (SIL)	Average Probability of Failure on Demand	Risk Reduction
4	$\geq 10^{-5}$ to $<10^{-4}$	>10,000 to ≤ 100,000
3	$\geq 10^{-4}$ to $<10^{-3}$	>1000 to ≤ 10,000
2	$\geq 10^{-3}$ to $<10^{-2}$	>100 to ≤ 1000
1	$\geq 10^{-2}$ to $<10^{-1}$	>10 to ≤ 100

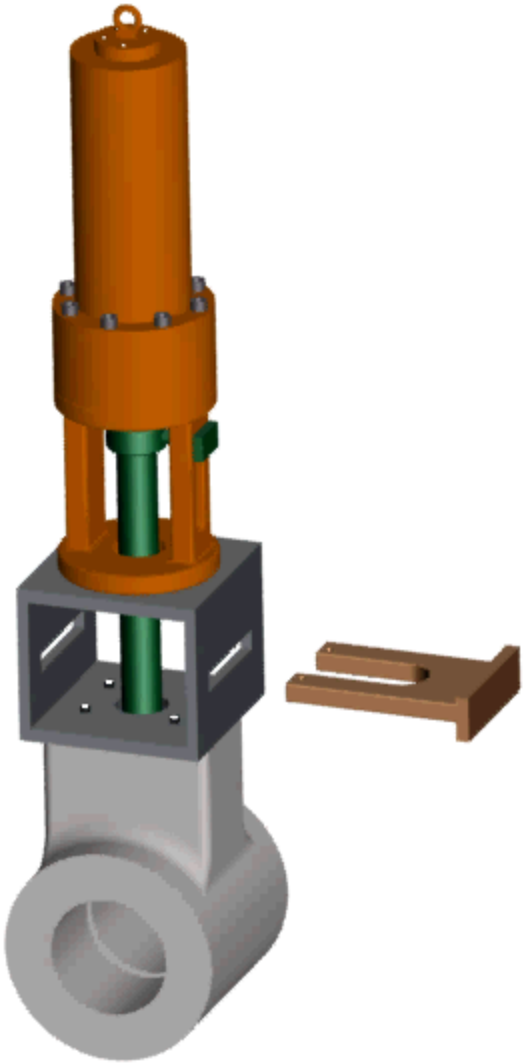
Table 4 – Safety integrity levels: frequency of dangerous failures per hour

CONTINUOUS MODE OF OPERATION	
Safety Integrity Level (SIL)	Frequency of Dangerous Failures Per Hour
4	$\geq 10^{-9}$ to $<10^{-8}$
3	$\geq 10^{-8}$ to $<10^{-7}$
2	$\geq 10^{-7}$ to $<10^{-6}$
1	$\geq 10^{-6}$ to $<10^{-5}$

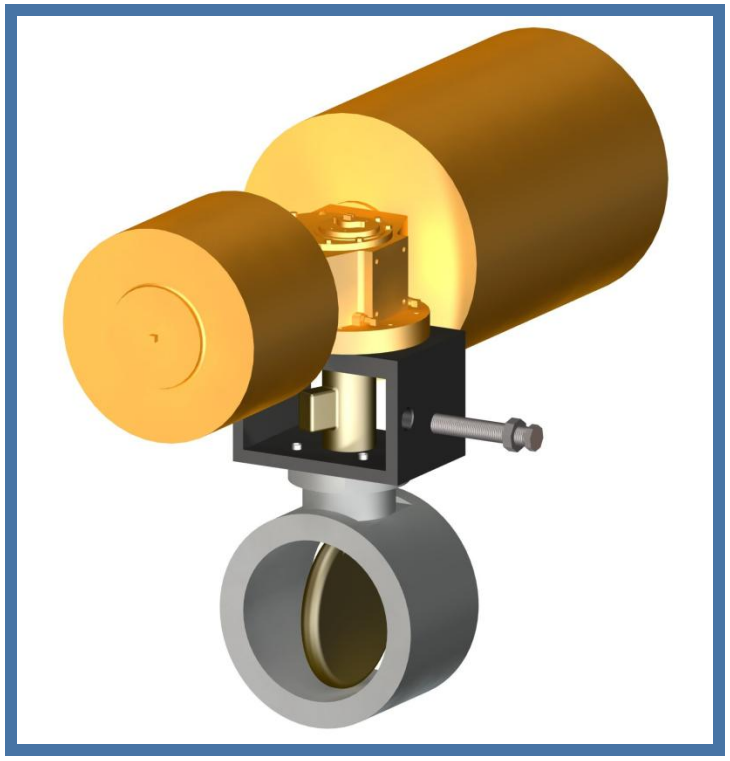
History of Mechanical PST - Linear

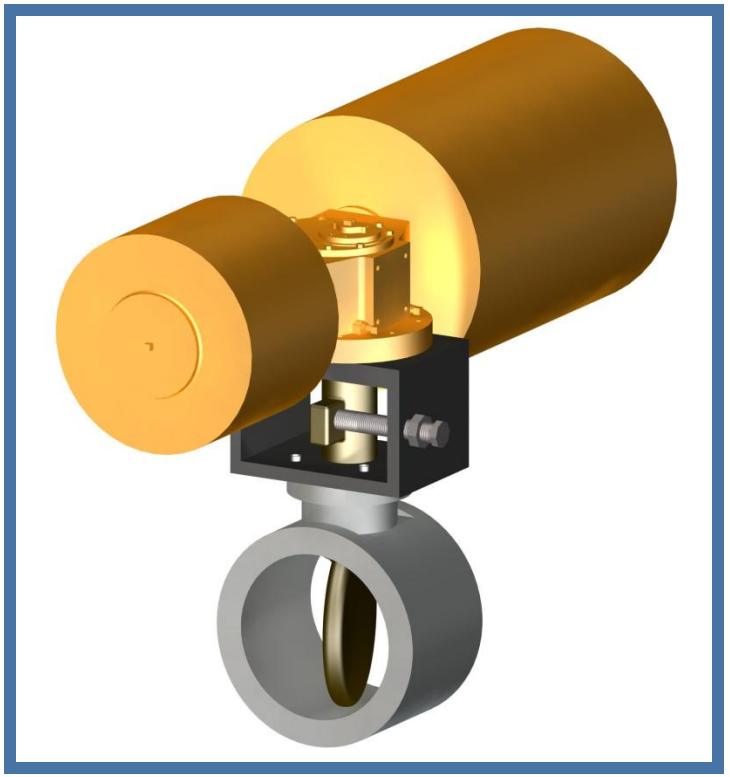


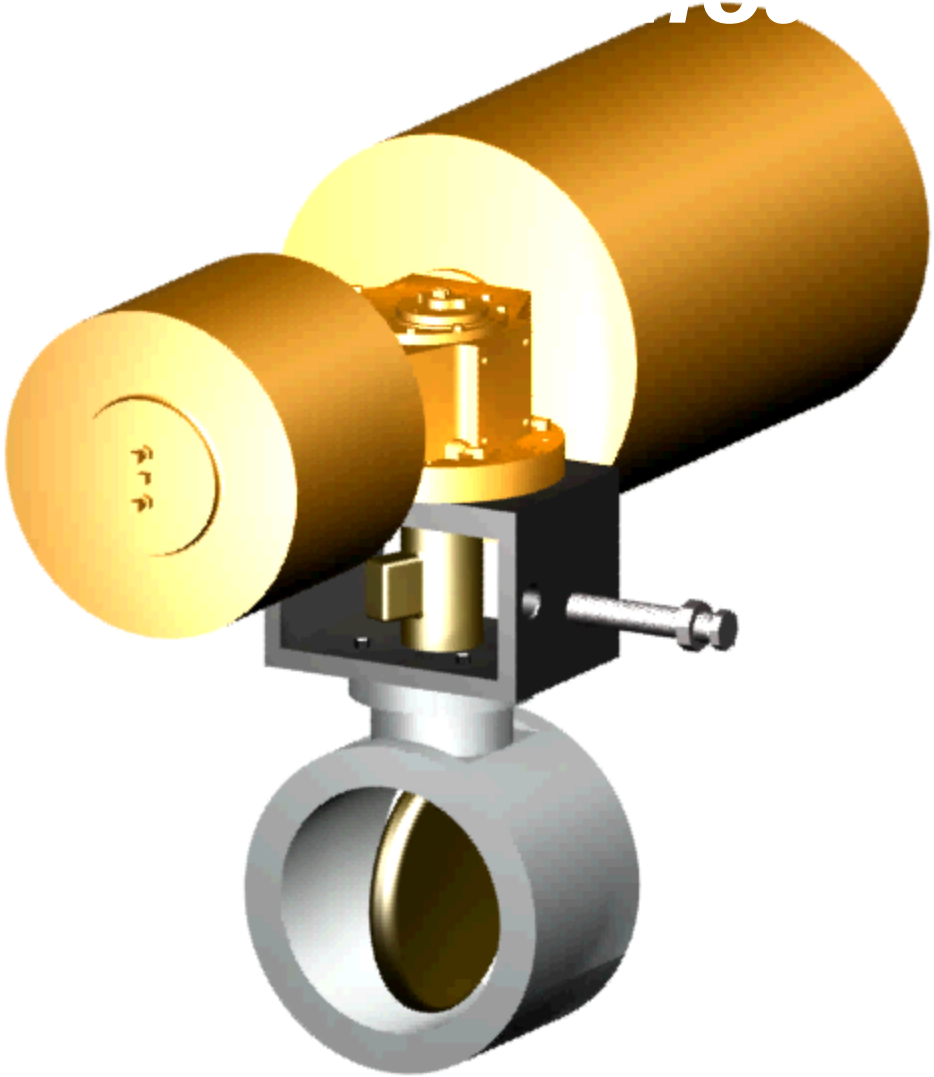




History of Mechanical PST - Rotary







History of Mechanical PST Early Design Disadvantages

- Each piece a unique design
  - Lack of consistency from plant to plant or even valve to valve.
  - Personnel training and product maintenance and replacement issues

- "Engineered in the shop" –reliability issues

History of Mechanical PST Early Design Disadvantages

- "Pinch points": fingers caught in the exposed mechanism.
- No safeguard against being left in the "engaged" position.
- Impractical to determine each unique device's impact on SIL.

Development of International Standards

IEC 61511 and ISA S84 allow for reduction of PFD_{AVG} by using partial stroke testing…

"For those applications where exercising the final trip element may not be practical"

Para 16.3.1.3 ANSI/ISA-84.00.01-2004 Part 2 (IEC 61511-2 Mod)

Development of International Standards

CHALLENGE TO ENGINEER:

“Increase reliability of our Safety System. Assure the Emergency Shutdown Valve (ESD) has partial stroke test capability.”

Development of International Standards

Standards are performance oriented, not prescriptive.

User decides method necessary to accomplish PST based on application, process, risk, etc.

Development of International Standards

DEFAULT THOUGHT:

"If I want this valve to do *something* I need to add *controls* to make it do that something."

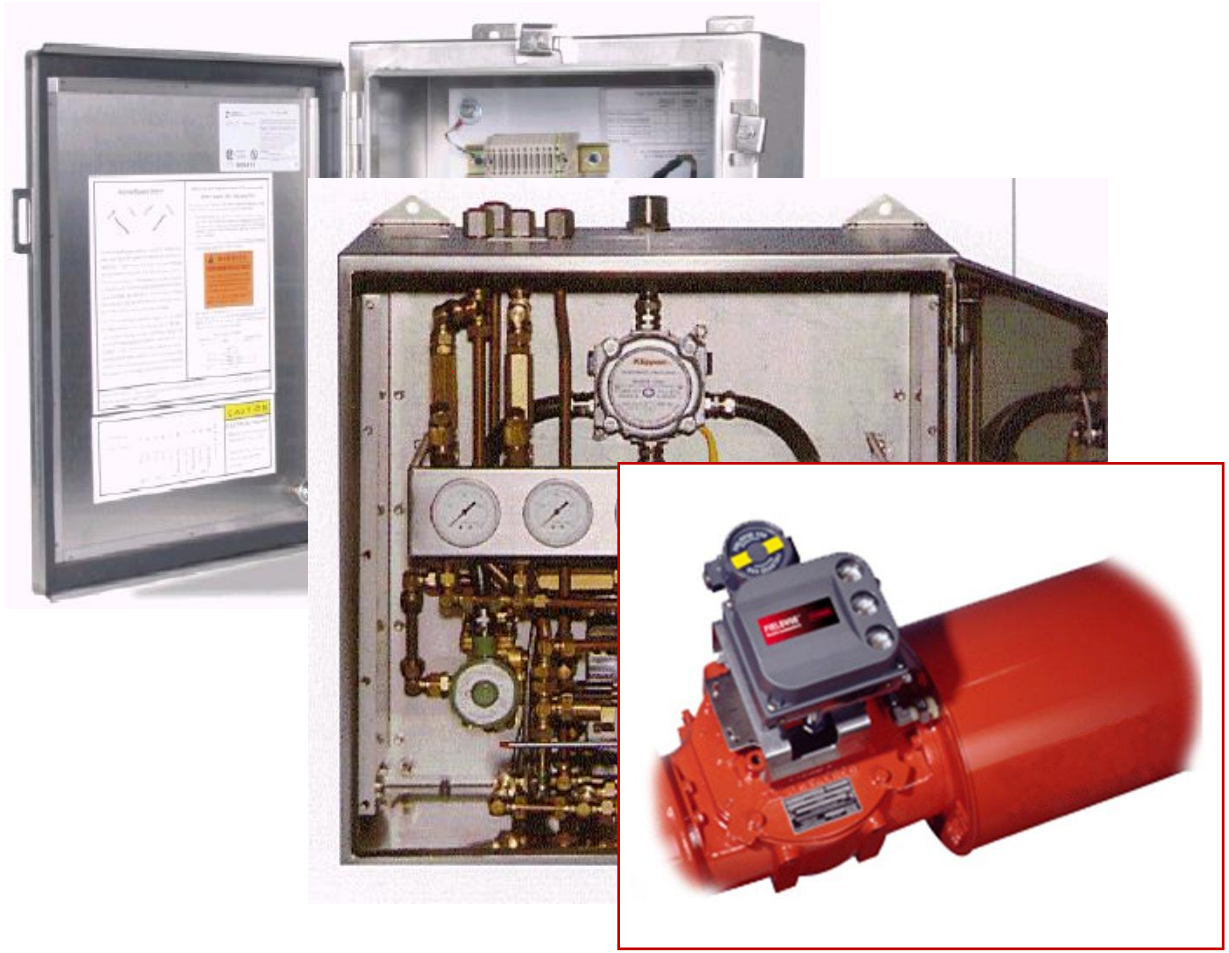
Instrumentation engineers
and vendors naturally converged ….

Development of International Standards

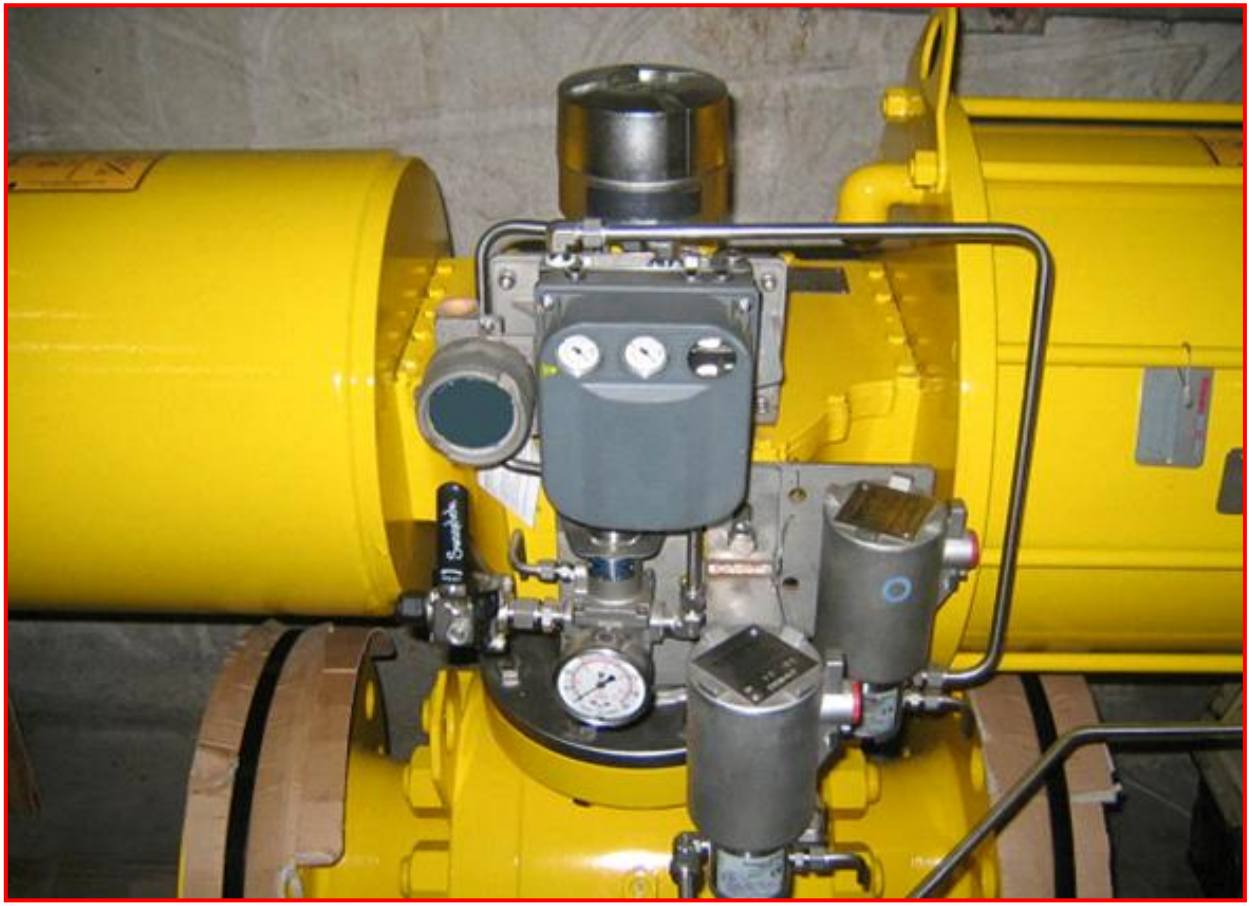
…to develop new and competing methods for accomplishing PST…

- Positioners
- Solenoid
- Other control-based systems

Controls Based PST Systems



Controls Based PST Systems



Development of International Standards

The Mechanical Approach:

Why take an already complicated control system and make it more complex to solve the problem of making it more reliable?

Is there a simpler, less complex solution that will result in an acceptable methodology for PST?

Mechanical Advantage: Benefits

No extraneous controls or devices in the control loop.

The control loop is kept as simple as possible

When the device is tested, all the actual components and controls stroke the ESD in the “real world” speed of operation.

Mechanical Advantage: Benefits

Cost Savings

- Simpler control loop
- No additional power or wiring
- No instrumentation commissioning
- No calibration
- Minimal personnel training
- No Software / No Software Training
- No Programmers
- Field Retrofit

Mechanical Advantage: Benefits

Reliable and Viable

- Metal-to-metal:
  - Valve cannot travel past set point
  - Reduced Spurious Maintenance Alarms

- Limit Switches can provide status to control room
- Human Interface / Visual Inspection
- SIL Capable / FMEDA

"Direct Interface" Mounting

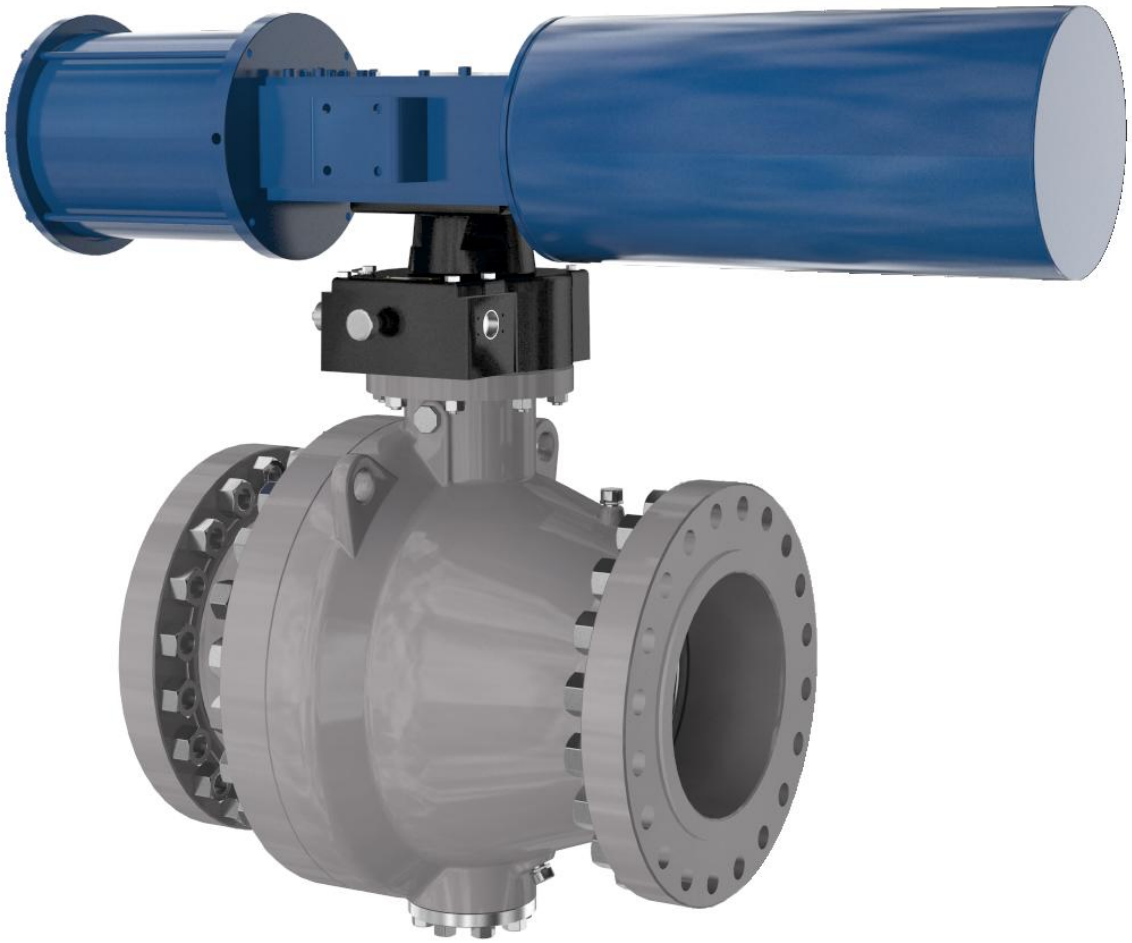
Any Actuator

Mechanical Device

Driver

Any Rotary Valve

“Direct Interface” Mounting



DYNATORQUE

Mounting and Torque Range

- Direct Interface Mount to small or large valves.
- For Actuator Torque output to millions of lb-in

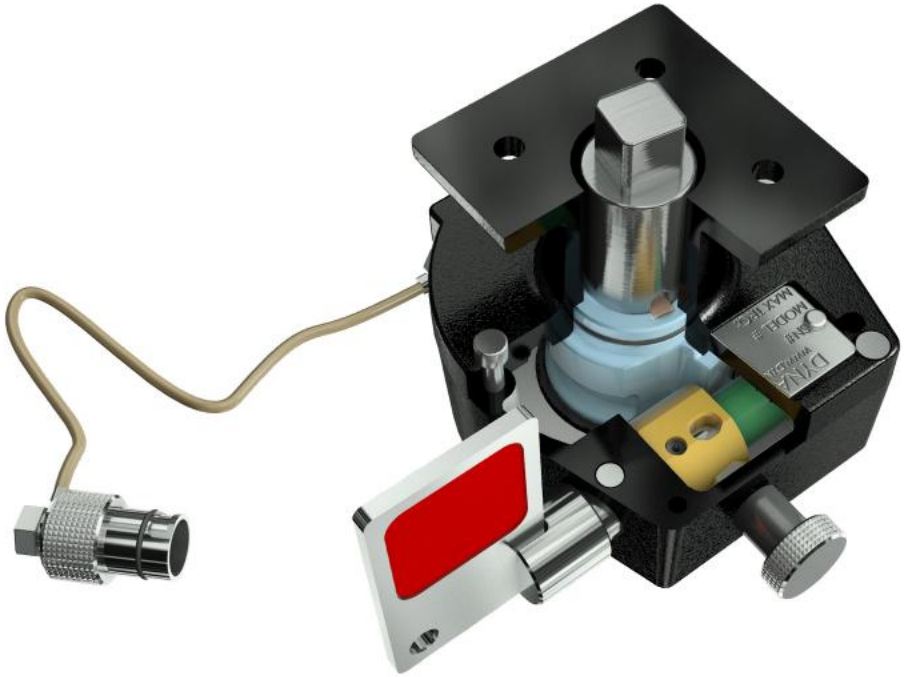
Mechanical Characteristics and Operation

Mechanical Characteristics and Operation

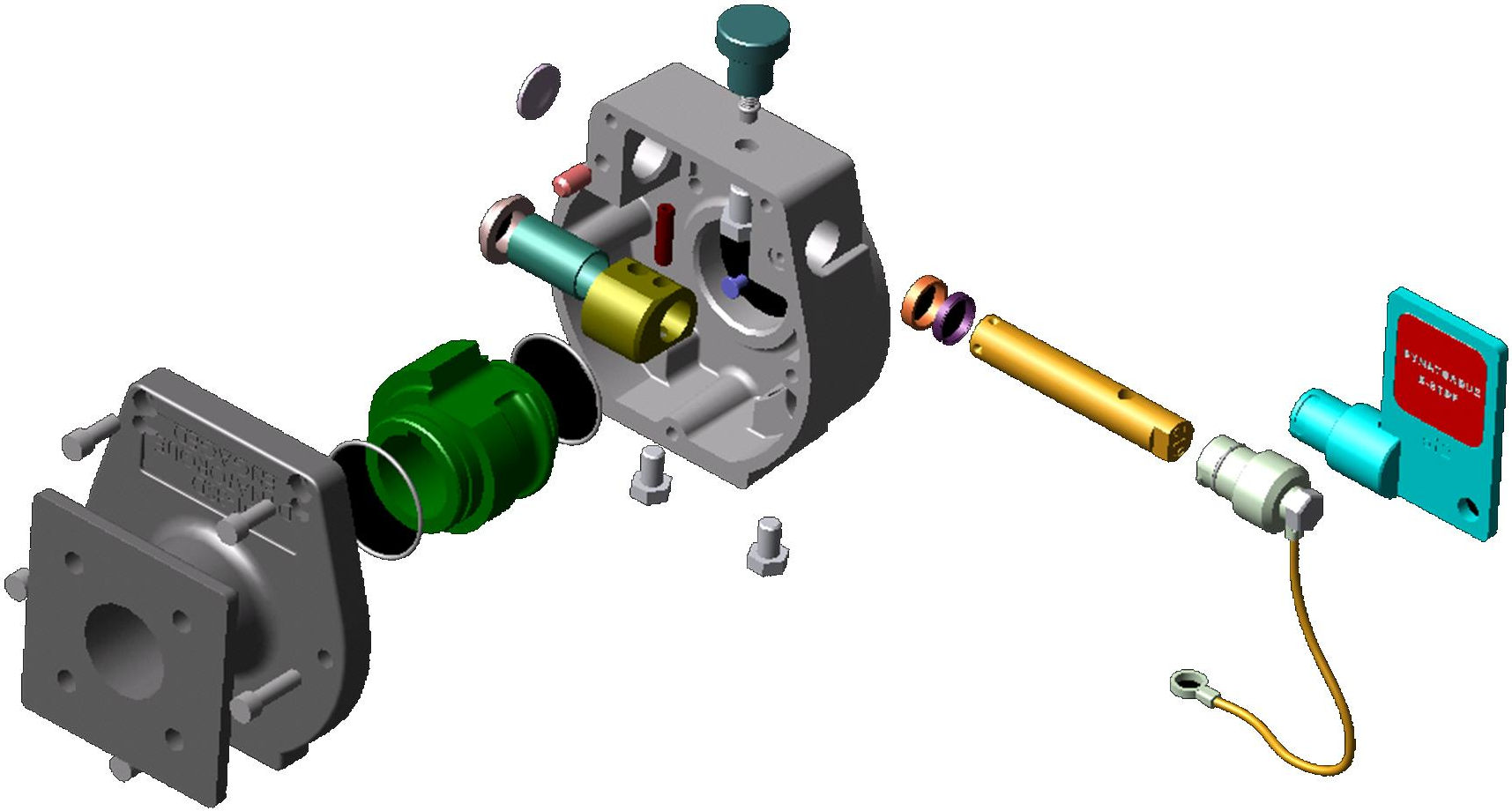
Mechanical Characteristics and Operation

DYNATORQUE

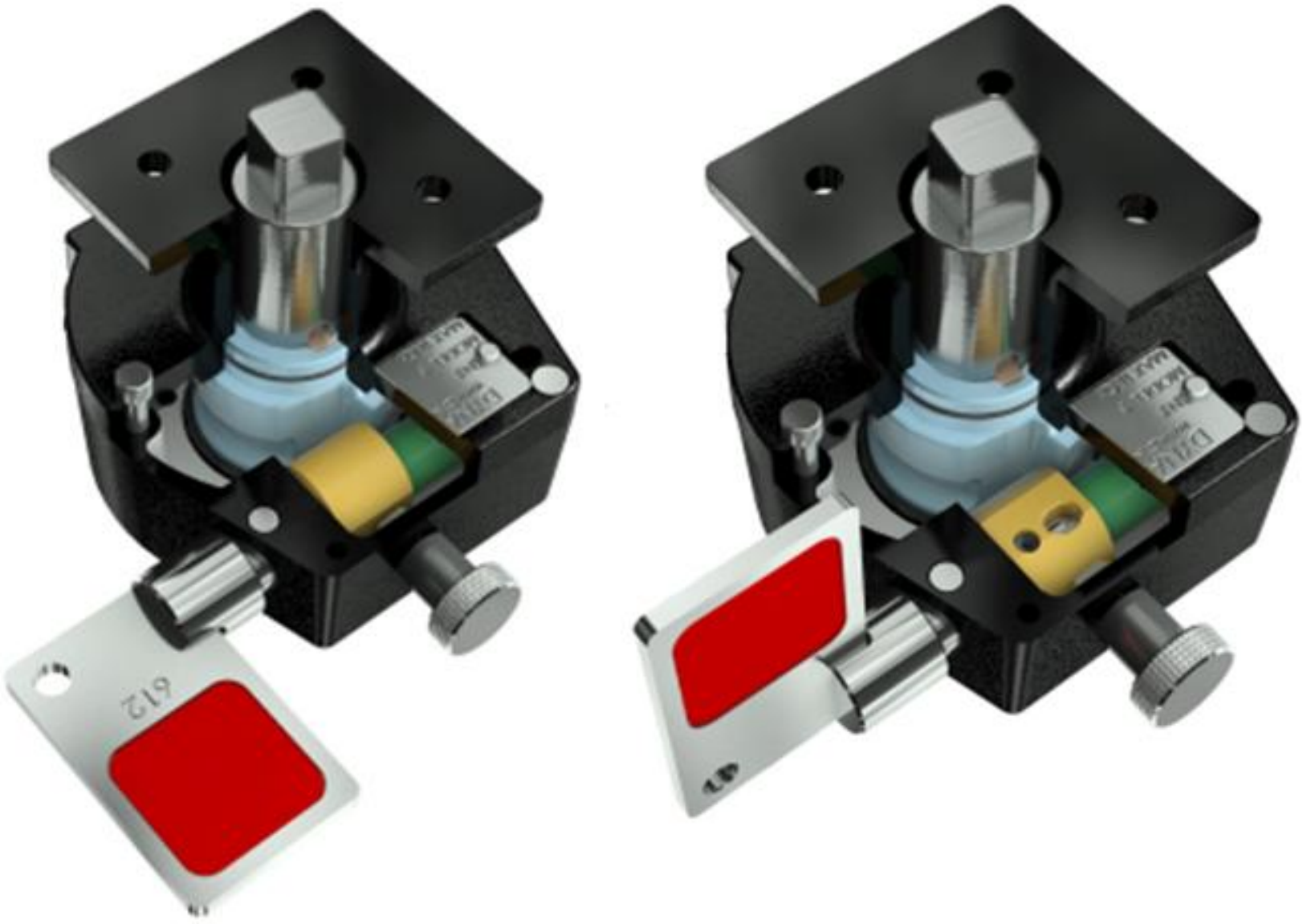
Mechanical Partial Stroke Test Device



ISA S-84 - IEC 61508 and IEC 61511
SIL Capable

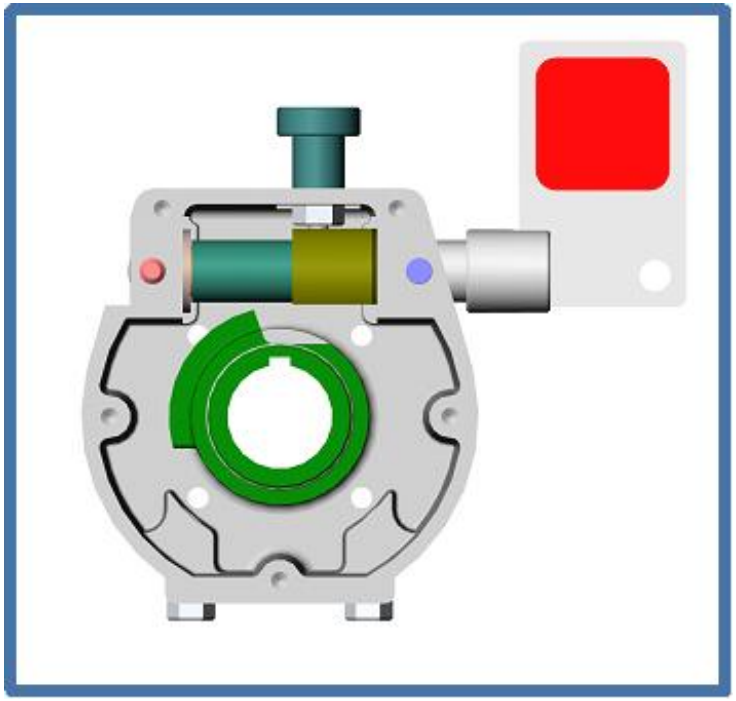


DYNATORQUE

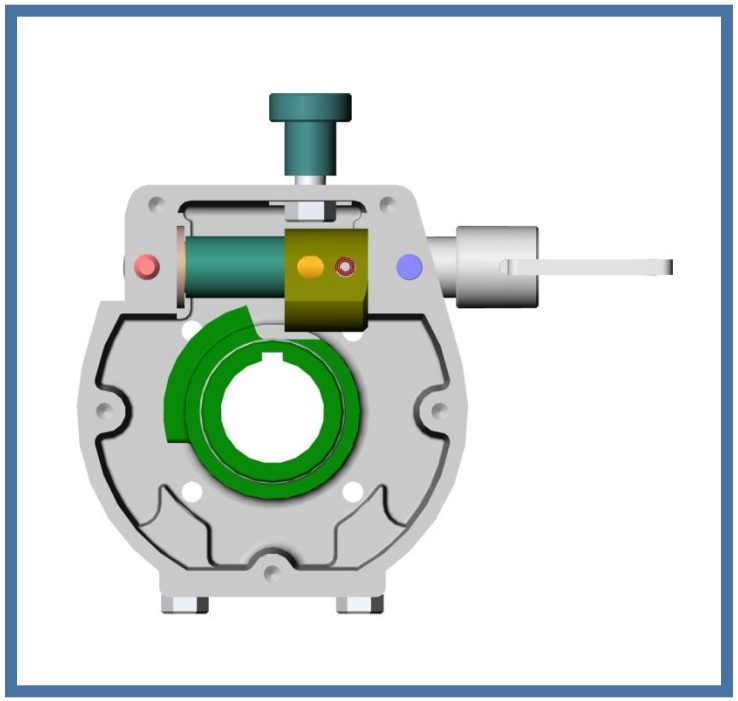


DYNATORQUE

Mechanical Characteristics and Operation

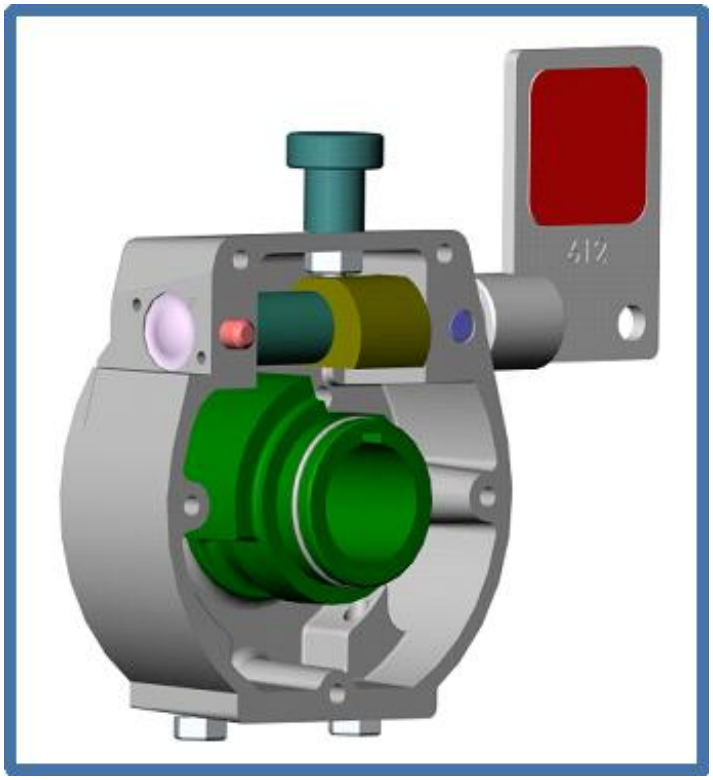


Disengaged

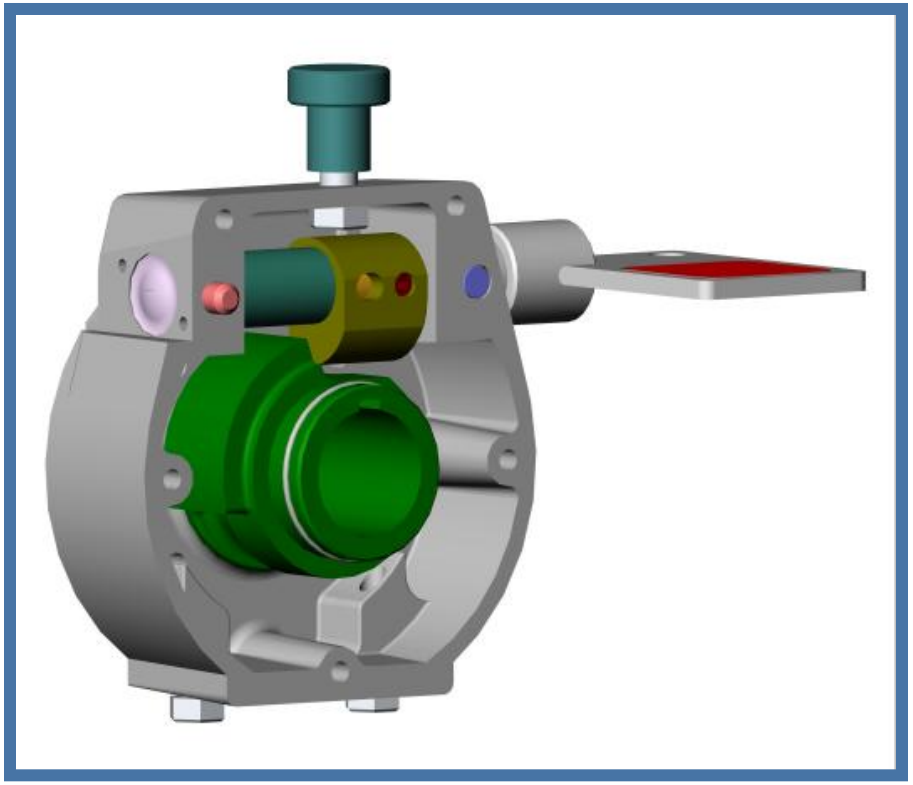


Engaged

Mechanical Characteristics and Operation

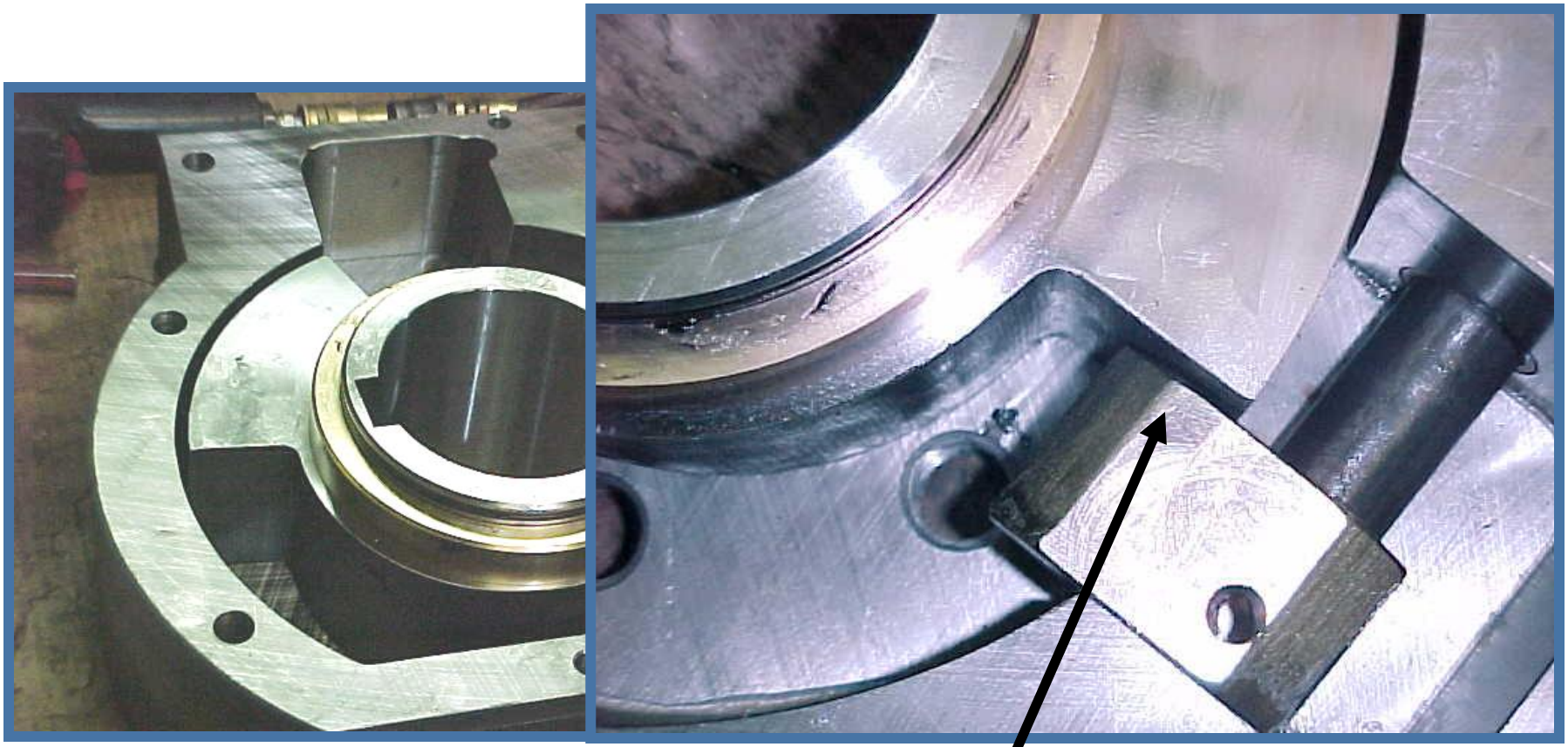


Disengaged



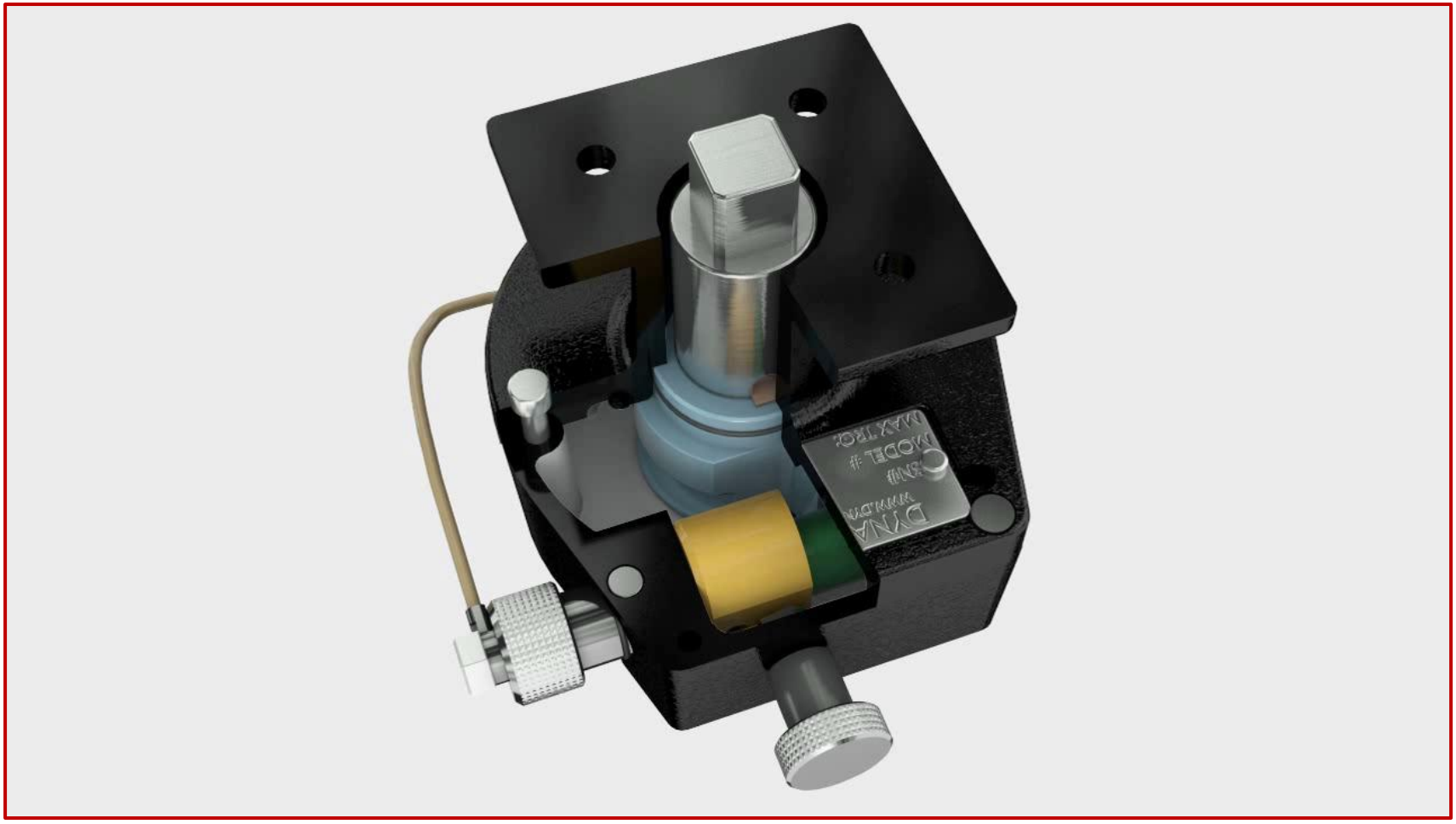
Engaged

Mechanical Advantage: Metal to Metal Safety

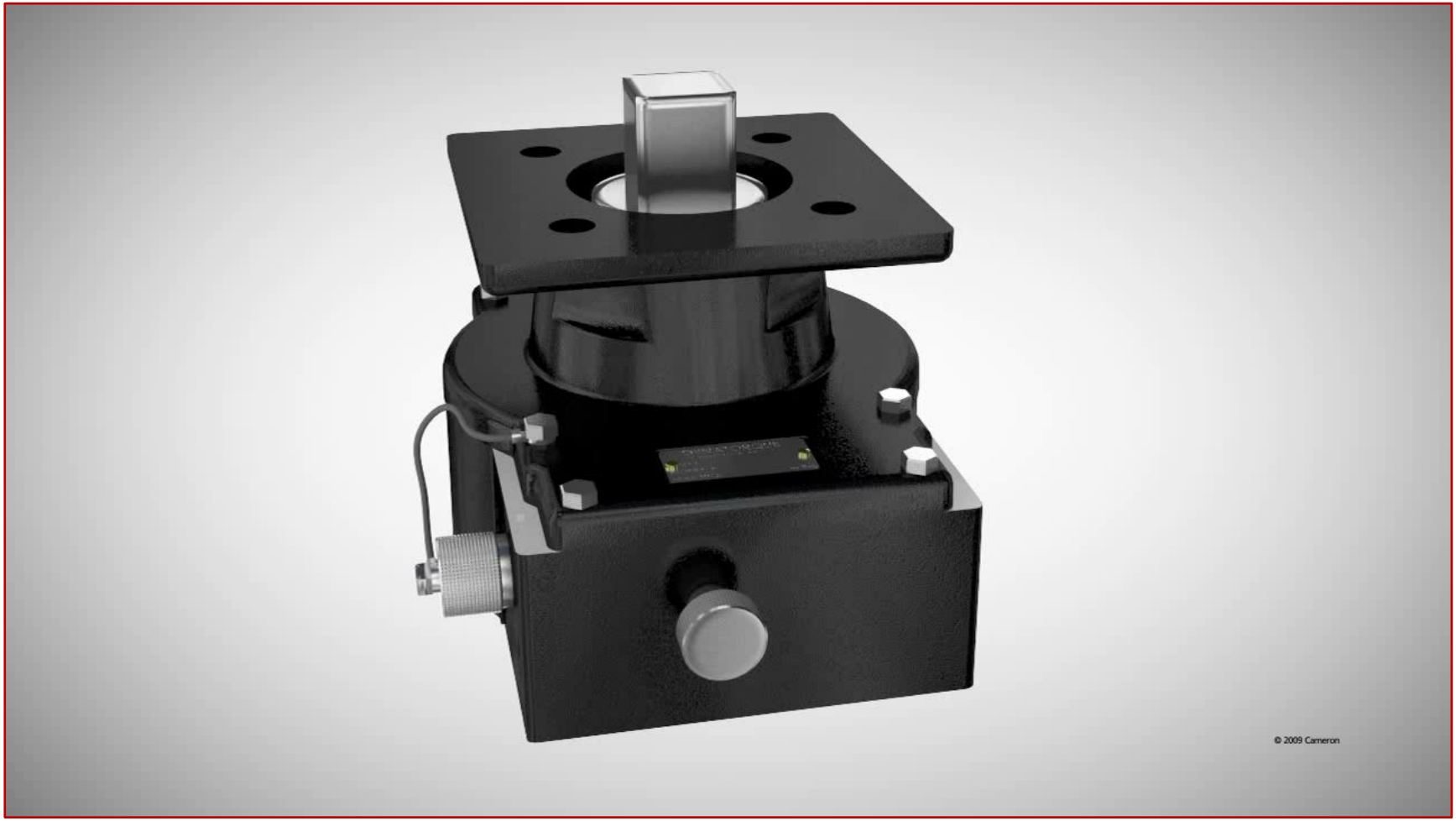


Mechanical Device fully “engaged”

Mechanical: How it Works



Operation of Mechanical PST Device



Human-Machine Interface

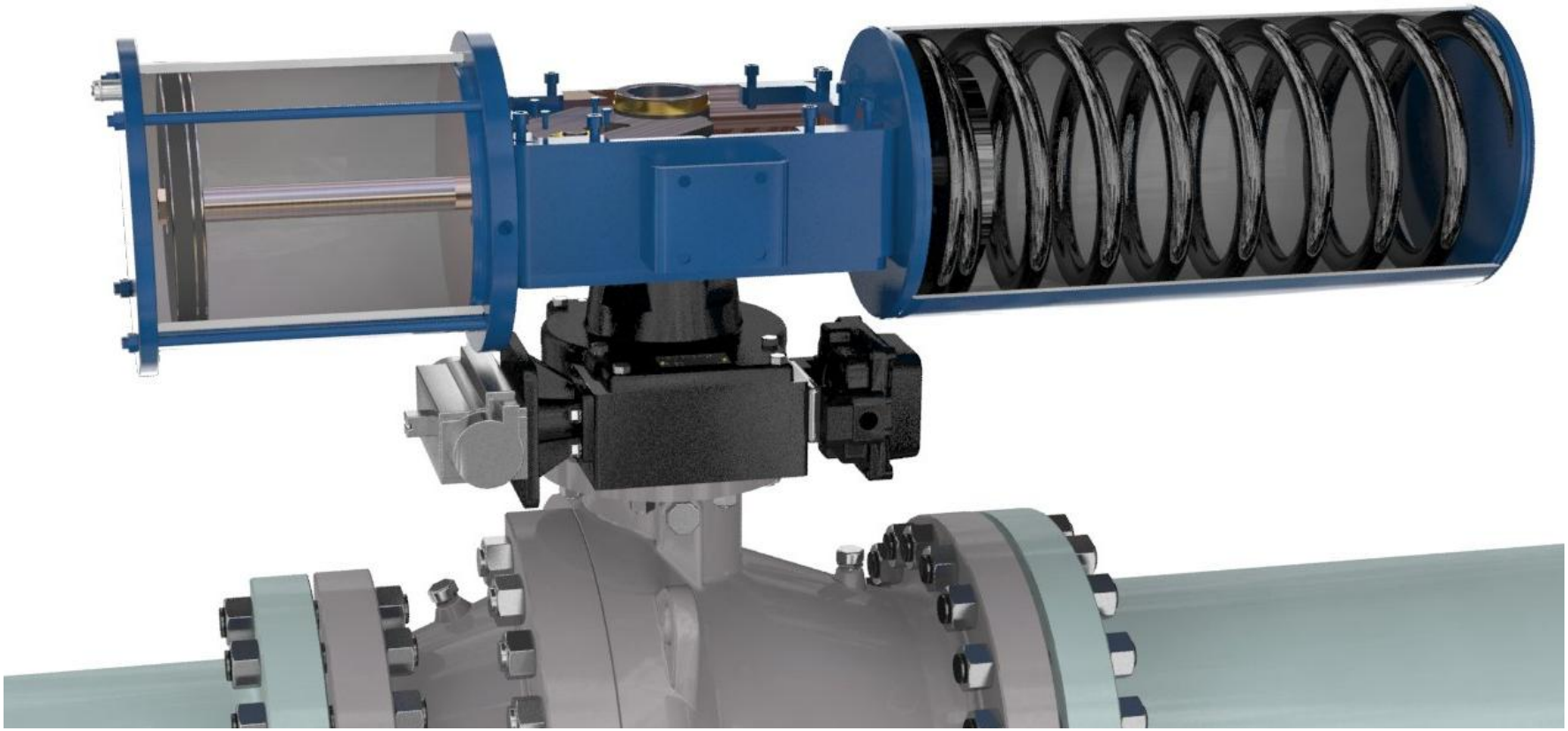
Inspection Requirements

16.3.2 Inspection:

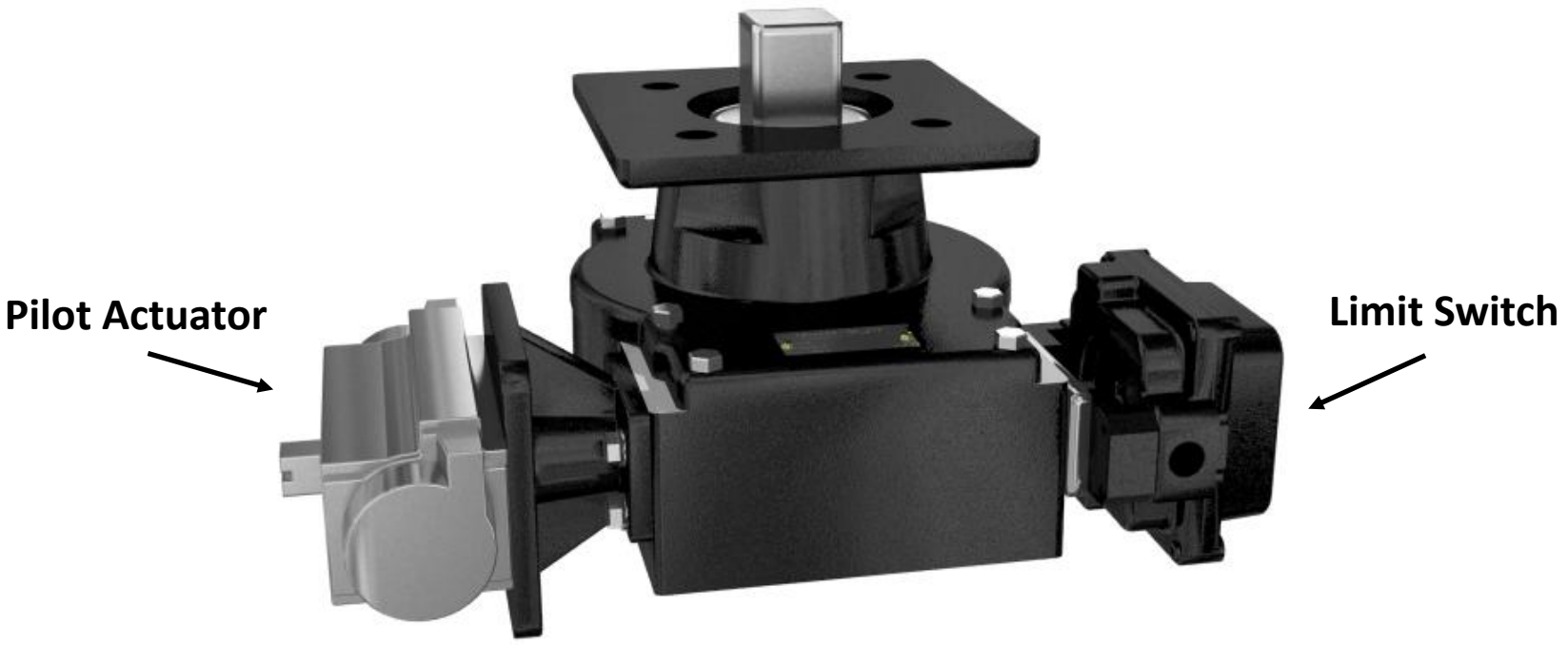
Each SIS shall be periodically visually inspected to ensure there are no unauthorized modifications and no observable deterioration (for example, missing bolts or instrument covers, rusted brackets, open wires, broken conduits, broken heat tracing, and missing insulation).

From 16.3.2 of ANSI/ISA-84.00.01-2004 Part 1 (IEC 61511-1 Mod) © ISA 2004

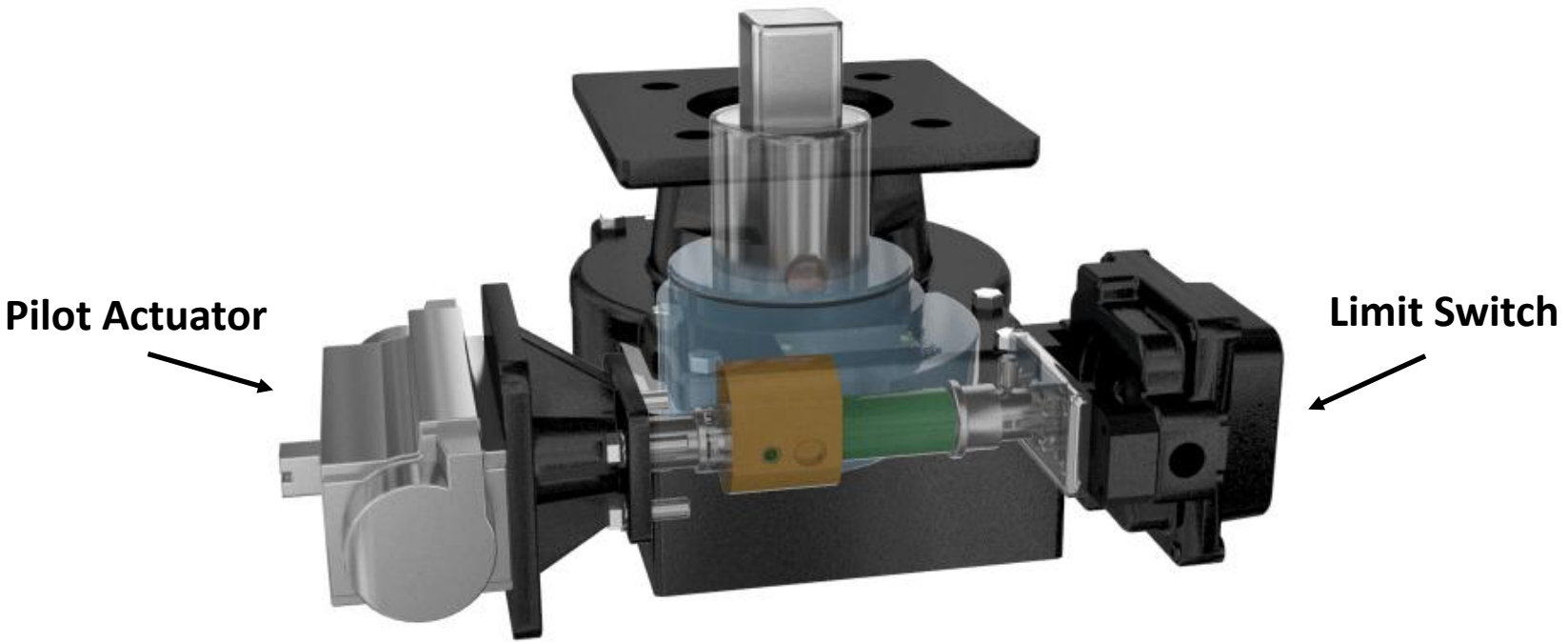
Remote Operation of Mechanical PST Device



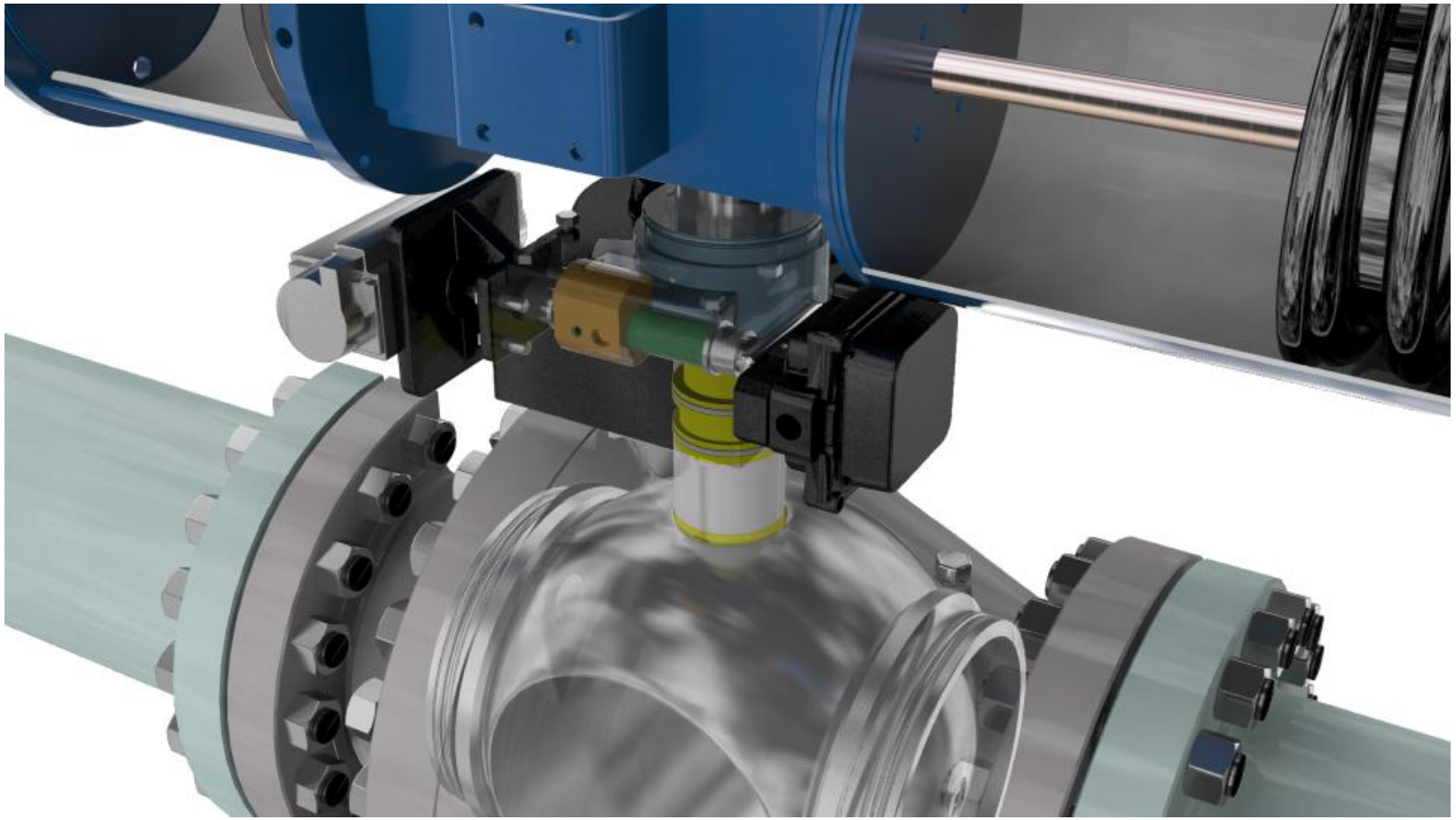
Remote Operation of Mechanical PST Device



Remote Operation of Mechanical PST Device

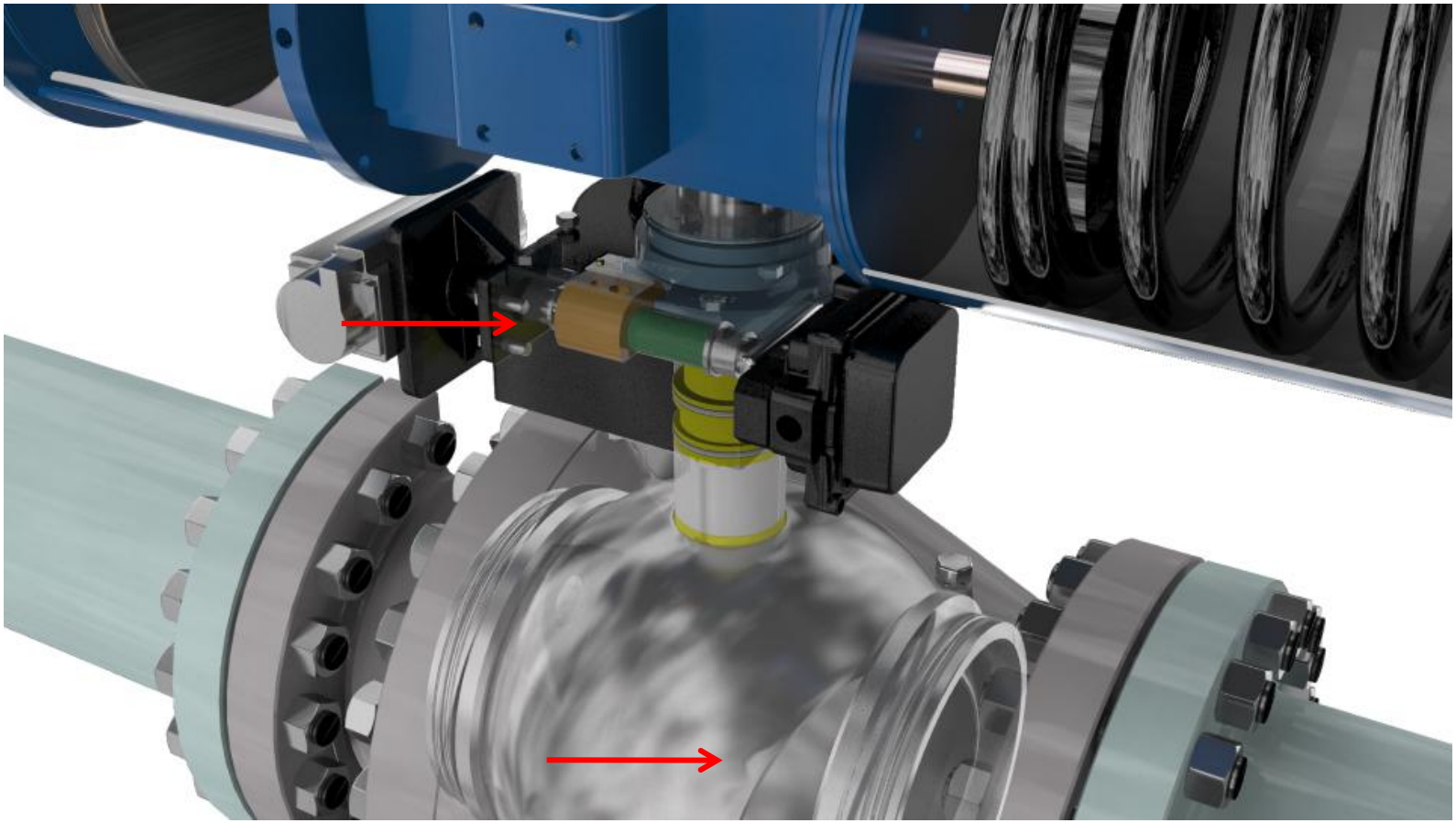


Remote Operation of Mechanical PST Device



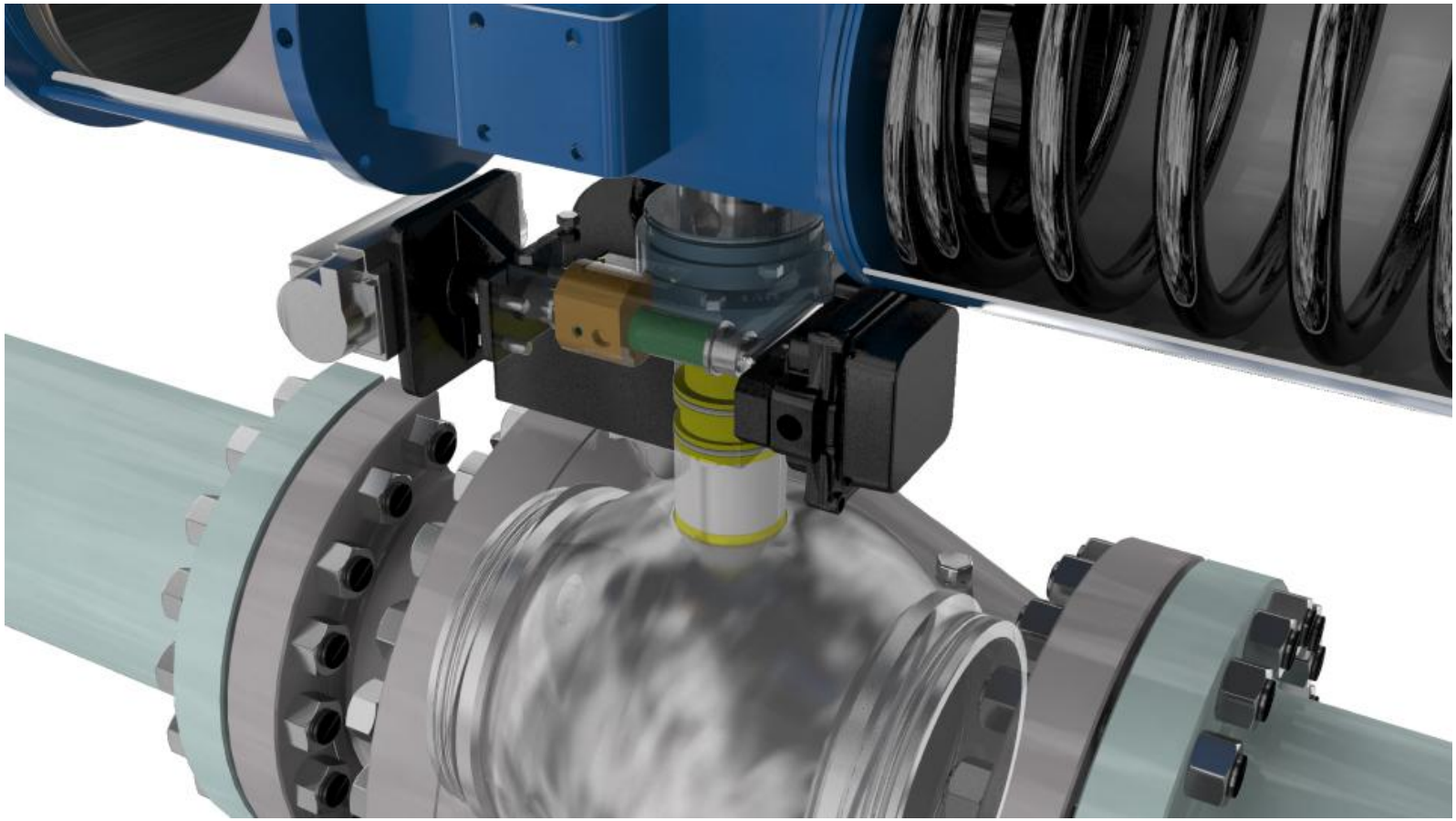
Pilot actuator spring holds engagement cam in disengaged position. Valve is free to fully open and close.

Remote Operation of Mechanical PST Device

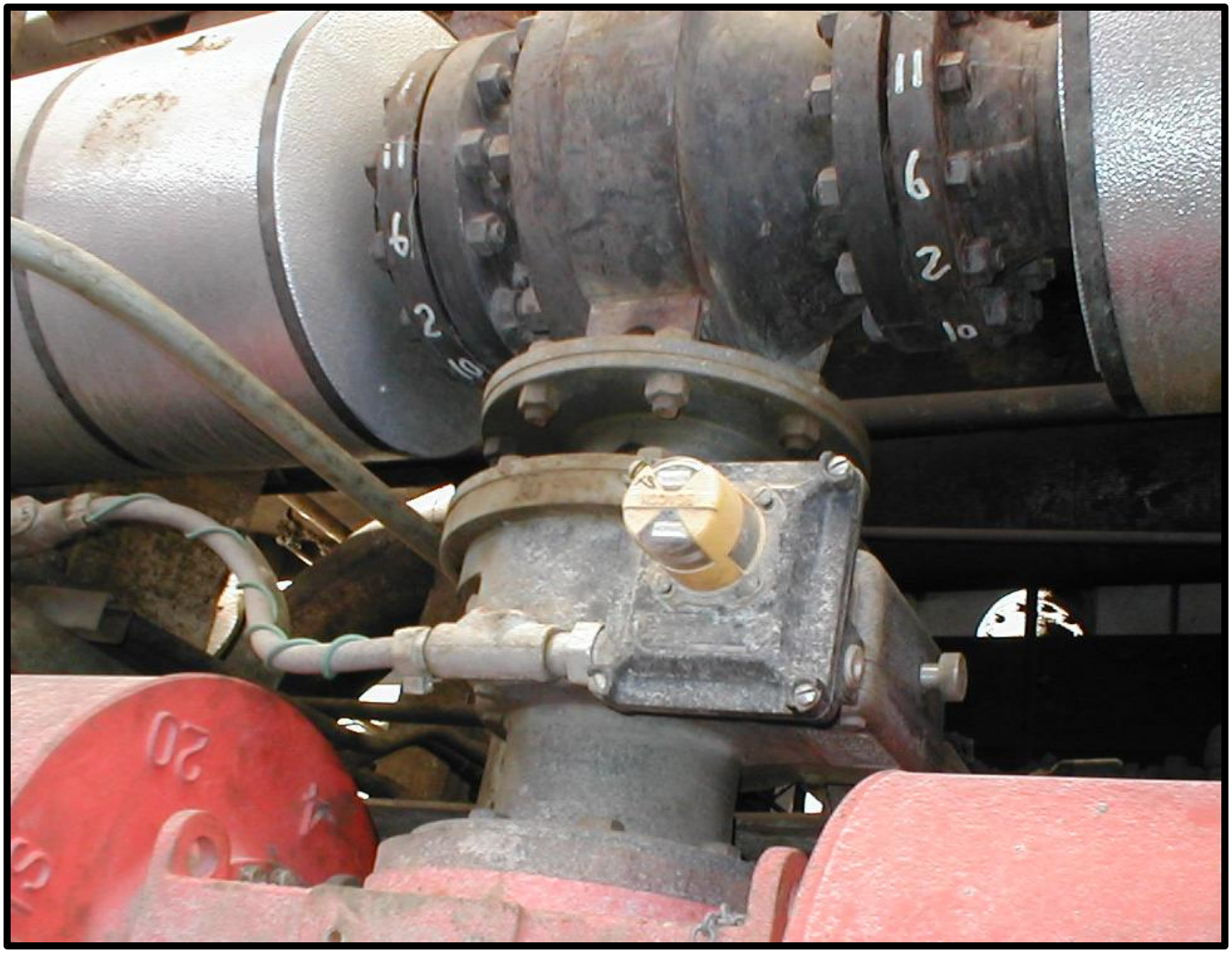


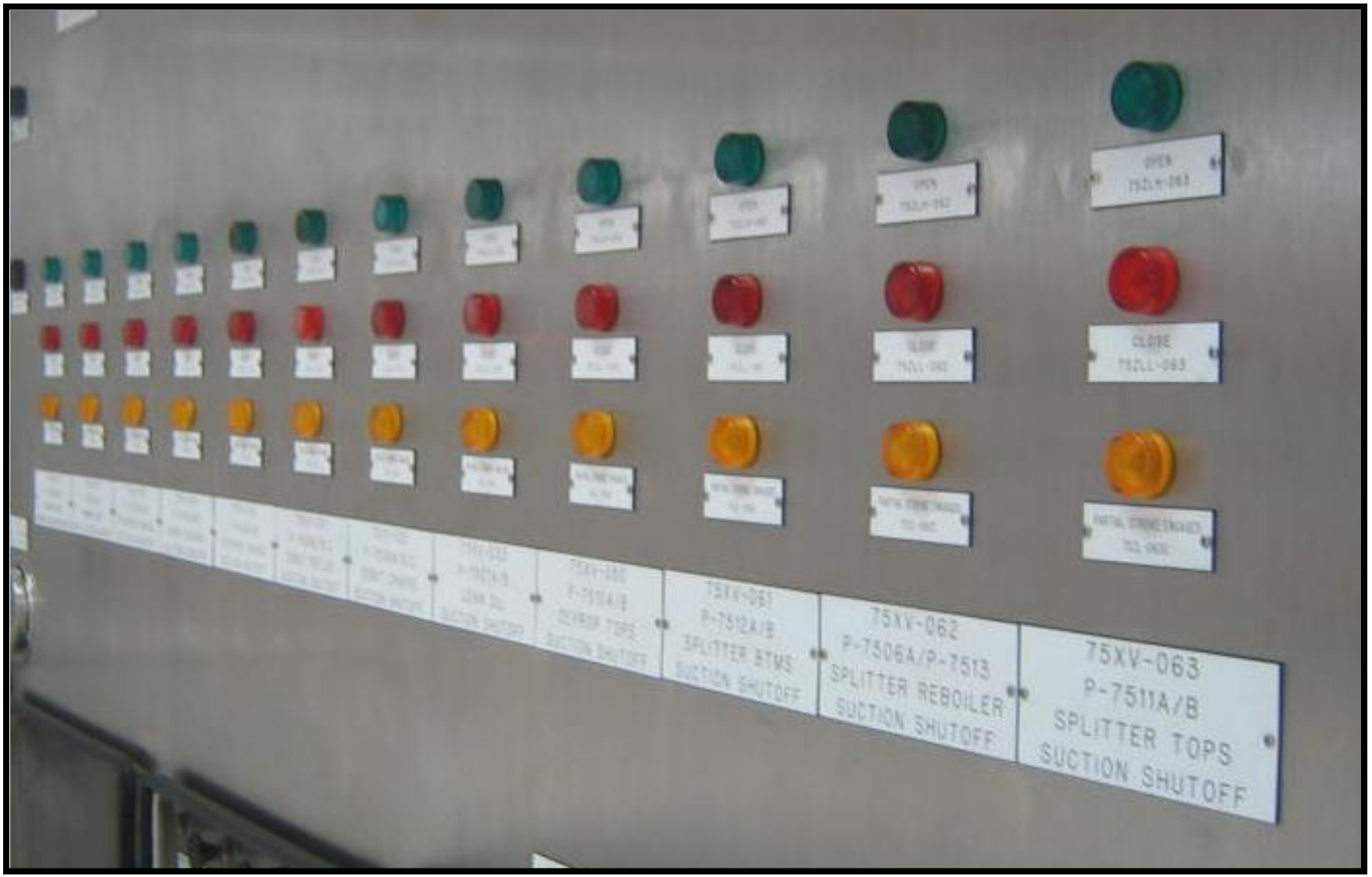
Pilot actuator is energized and engagement cam in is engaged position. Valve is partially stroked.

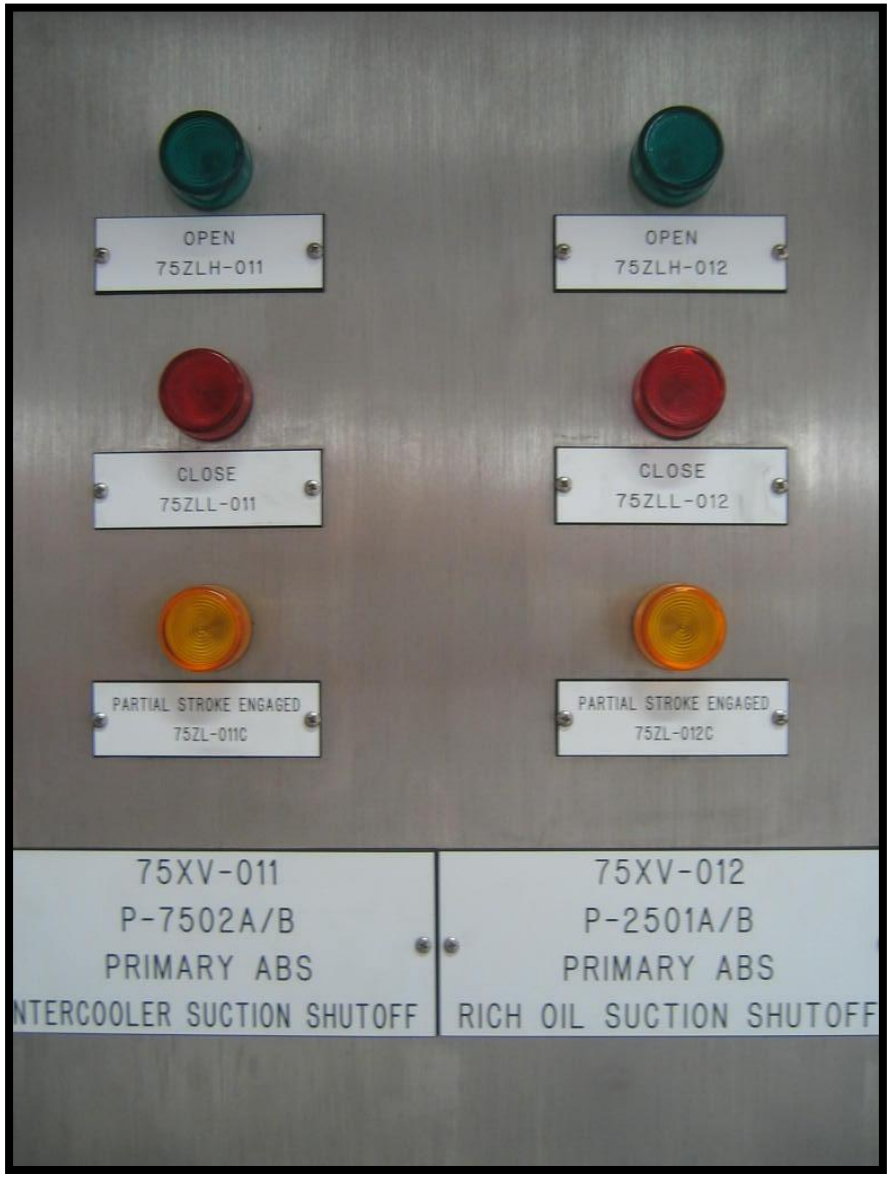
Remote Operation of Mechanical PST Device



All devices in normal operation condition. Test is complete.

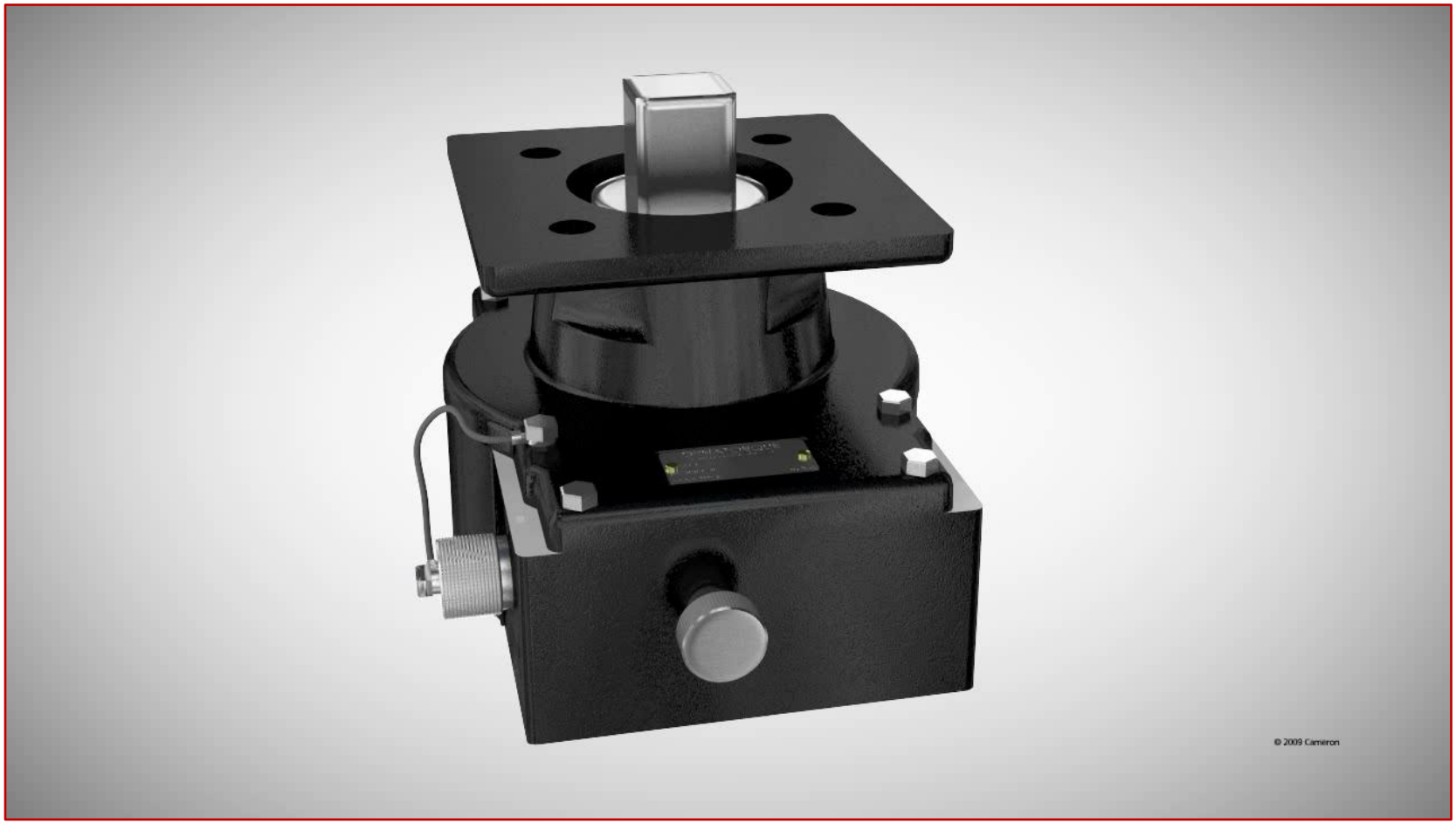



75XV-062
P-7506A/P-7513
SPLITTER REBOILER
SUCTION SHUTOFF
75XV-063
P-7511A/B
SPLITTER TOPS
SUCTION SHUTOFF

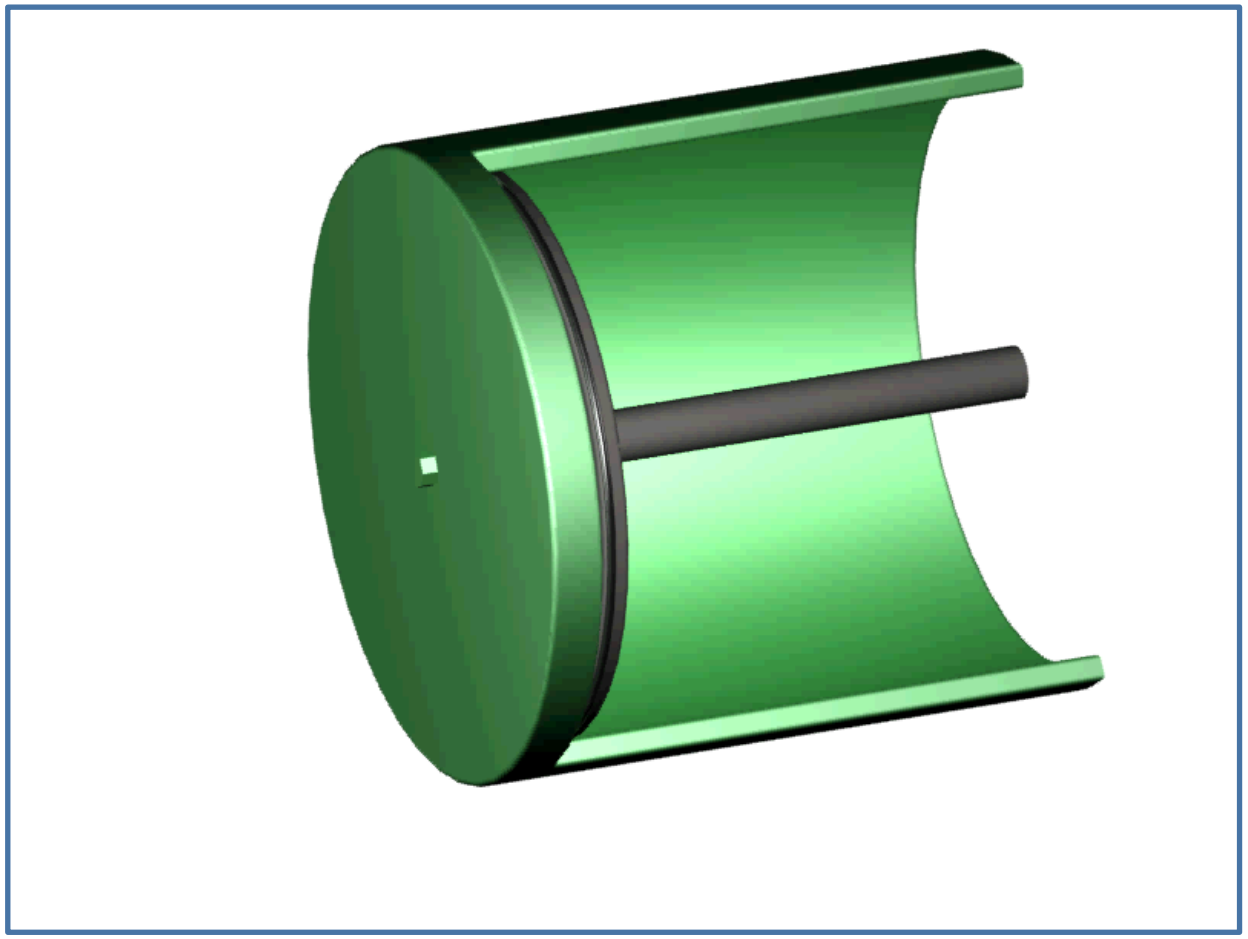

OPEN
75ZLH-011
OPEN
75ZLH-012
CLOSE
75ZLL-011
CLOSE
75ZLL-012
PARTIAL STROKE ENGAGED
75ZL-011C
PARTIAL STROKE ENGAGED
75ZL-012C
75XV-011
P-7502A/B
PRIMARY ABS
NTERCOOLER SUCTION SHUTOFF
75XV-012
P-2501A/B
PRIMARY ABS
RICH OIL SUCTION SHUTOFF


PARTIAL STROKE ENGAGED
75ZL-063C

Remote Operation of Mechanical PST Device



Pneumatic Actuators in the Real World



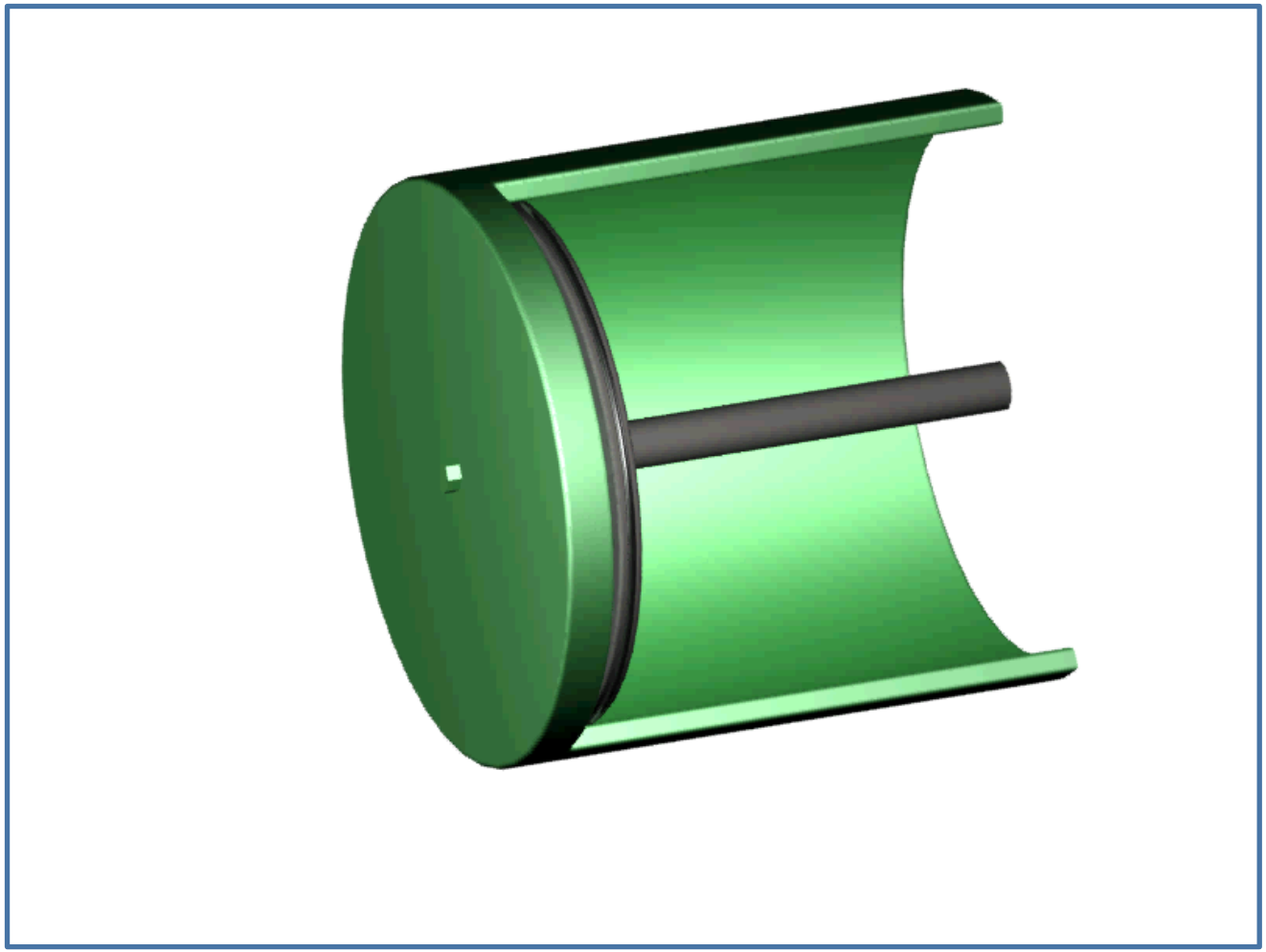
“Ideal Cylinder”: Smooth Acting

Pneumatic Actuators in the Real World

ESD is Seldom Stroked

Cylinders are not necessarily repeatable

Stiction is “normal”

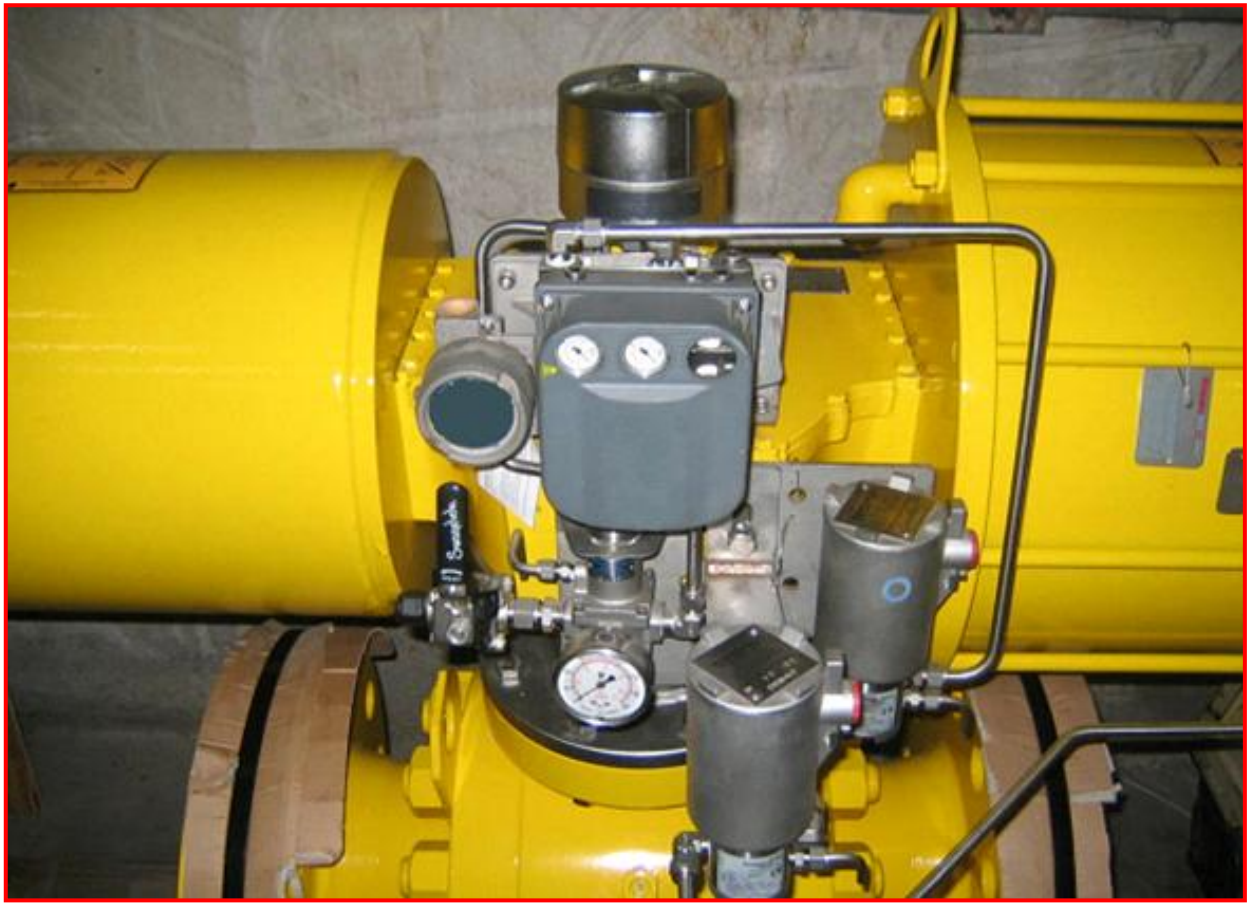


“Real World Cylinder”: Stiction

Pneumatic Actuators in the Real World

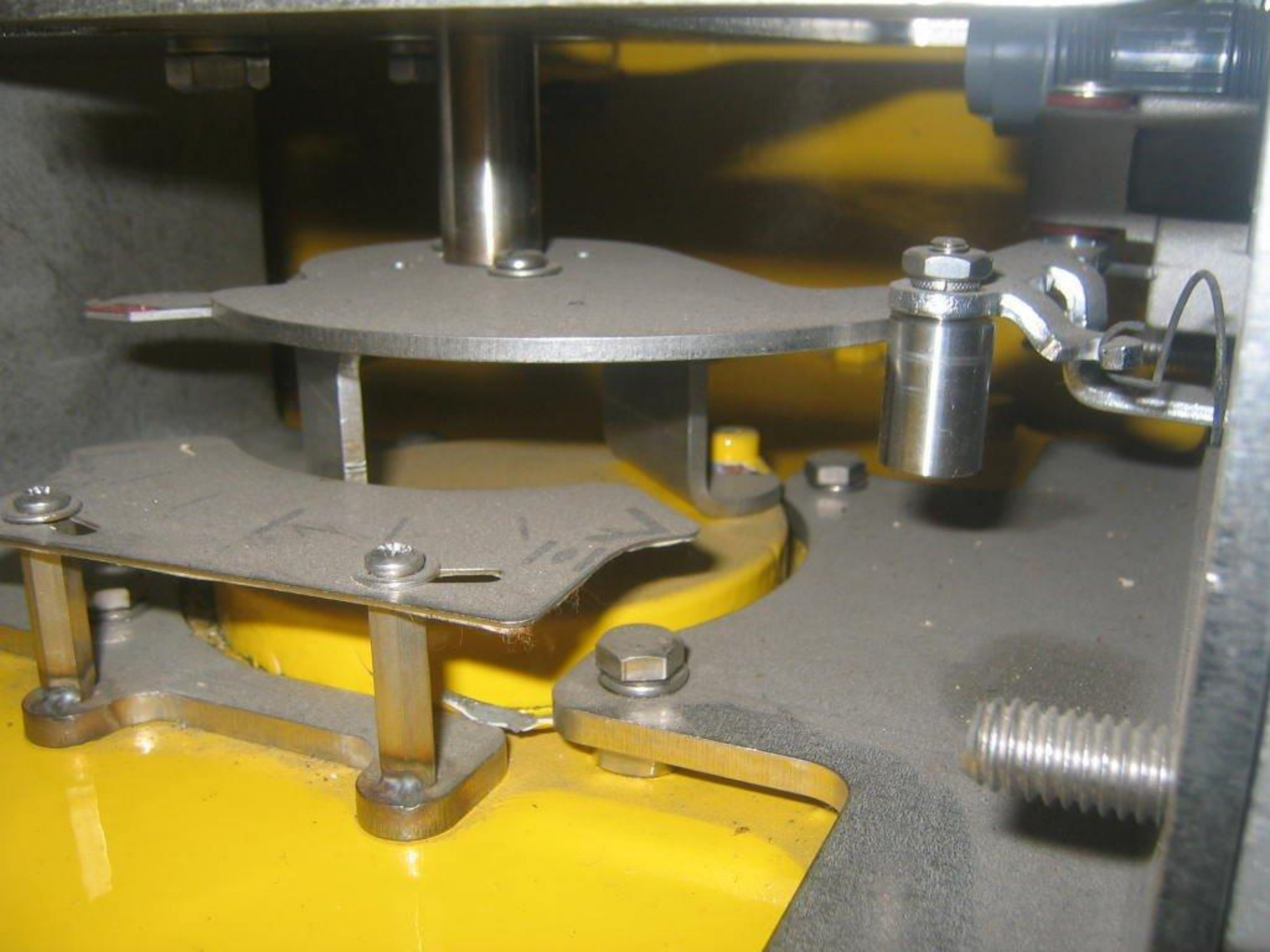
- Stiction is “normal”
- “normal” may equal spurious alarms
- “normal” may equal costly non-essential maintainence

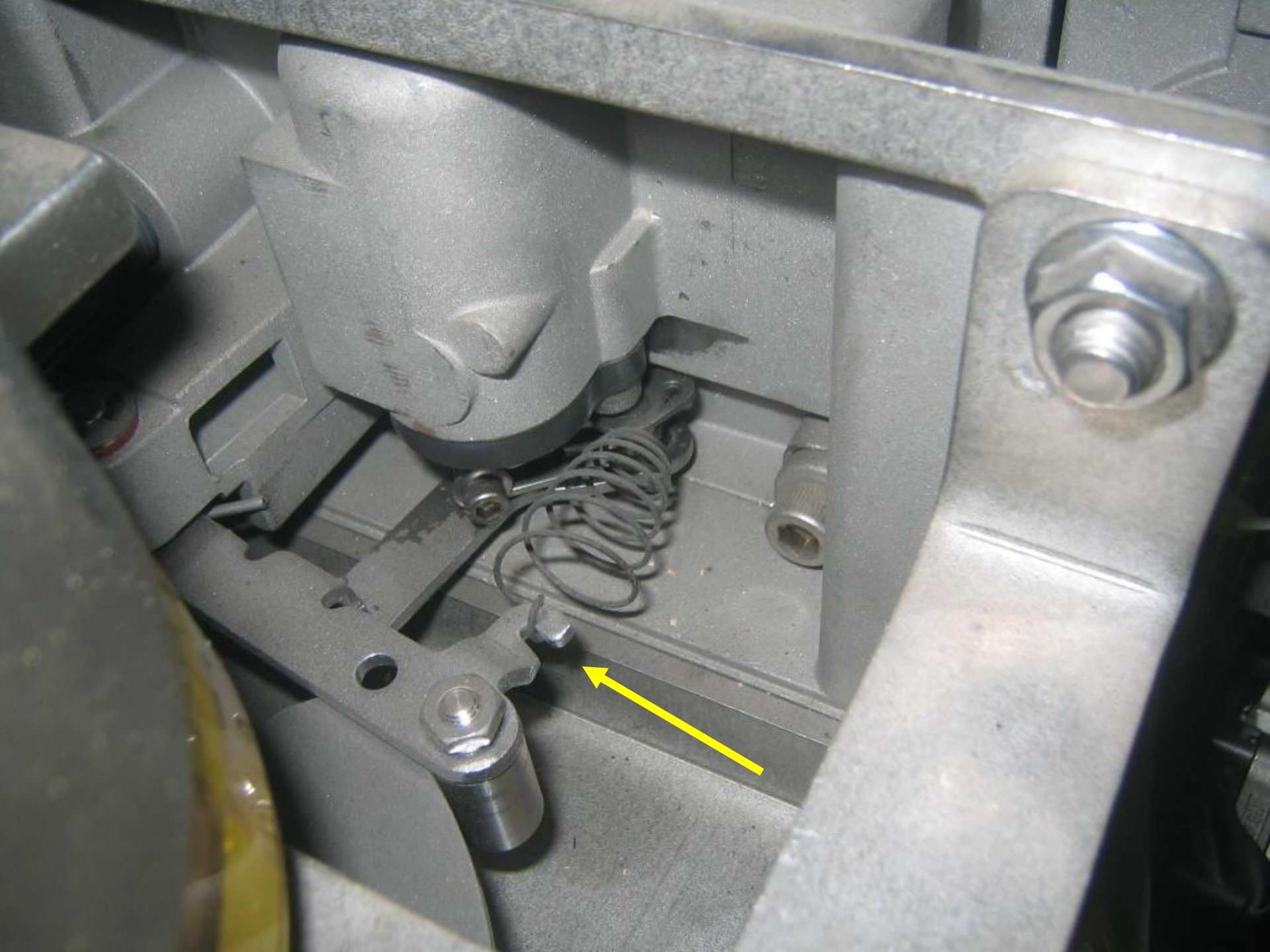
Mechanical Aspects of Electronic Systems



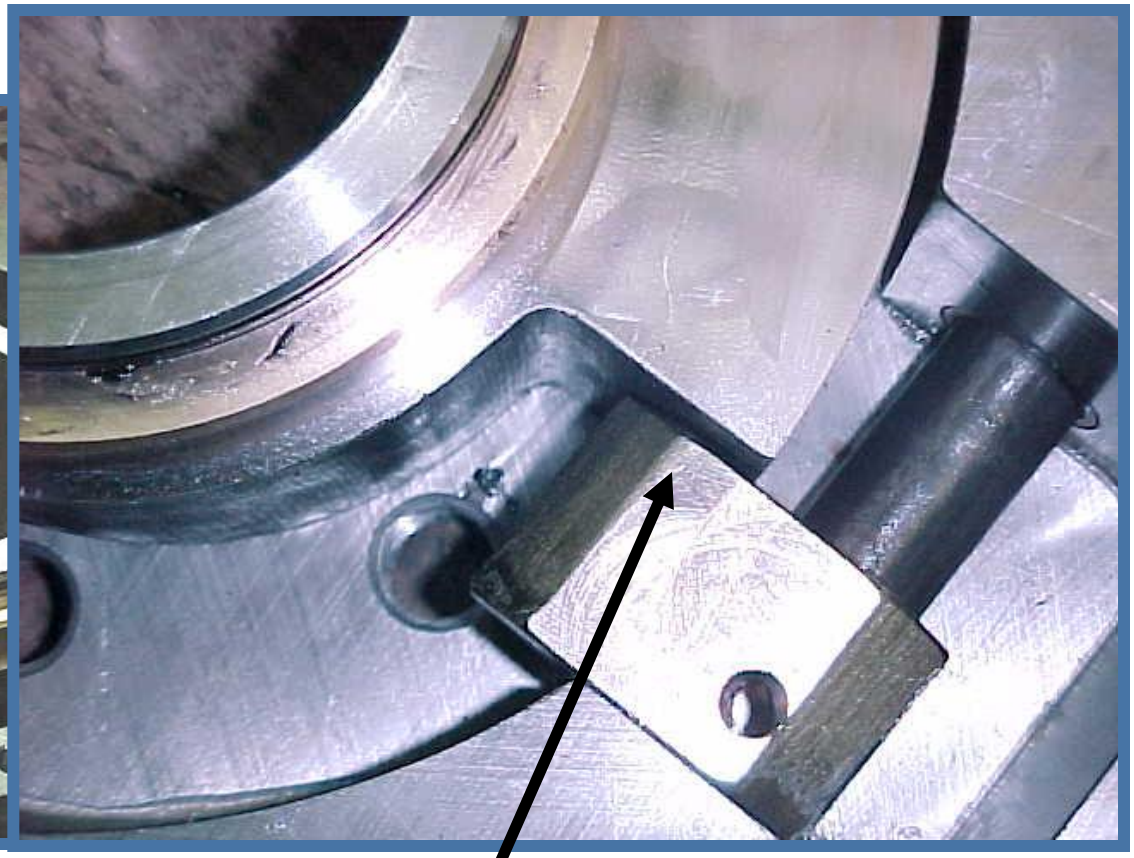

Swagelok
OPEN


DVC6000 series digital valve controller requires one of the following
AMS Suite: Intelligent Device Manager - DVC6000 Device Rev 2.
375 Field Communicator - DVC6000 Device Rev 2.
475 Field Communicator - DVC6000 Device Rev 2.





Mechanical Advantage: Metal to Metal Safety



Device fully "engaged"

Safety Integrity Levels (SIL) reflect relative levels of risk reduction

Table 3 – Safety integrity levels: probability of failure on demand

DEMAND MODE OF OPERATION		
Safety Integrity Level (SIL)	Average Probability of Failure on Demand	Risk Reduction
4	$\geq 10^{-5}$ to $<10^{-4}$	>10,000 to ≤ 100,000
3	$\geq 10^{-4}$ to $<10^{-3}$	>1000 to ≤ 10,000
2	$\geq 10^{-3}$ to $<10^{-2}$	>100 to ≤ 1000
1	$\geq 10^{-2}$ to $<10^{-1}$	>10 to ≤ 100

Table 4 – Safety integrity levels: frequency of dangerous failures per hour

CONTINUOUS MODE OF OPERATION	
Safety Integrity Level (SIL)	Frequency of Dangerous Failures Per Hour
4	$\geq 10^{-9}$ to $<10^{-8}$
3	$\geq 10^{-8}$ to $<10^{-7}$
2	$\geq 10^{-7}$ to $<10^{-6}$
1	$\geq 10^{-6}$ to $<10^{-5}$

Mechanical Device Impact on SIL

Failure Modes, Effects and Diagnostic Analysis (FMEDA) to determine Average Probability of Failure on Demand (PDF_{AVG})

Mechanical Device Impact on SIL

Mechanical Device shown to have PFD_{AVG} as low as 1.36E-04

Rachel Amkreutz, Lindsey Bredemeyer, Failure Modes, Effects and Diagnostic Analysis, Project D-Stop Partial Stroke Test Device, Exida

Mechanical Device Impact on SIL

Mechanical PST Device PFD_{AVG} 1.36E-04

Generic scotch yoke actuator » 1.5E-03
Generic rack and pinion actuator » 5.7E-03
Generic floating ball valve » 3.5E-03
Generic resilient butterfly valve » 5.7E-03
Generic HPBV / Triple Offset Butterfly valves » 8.5E-03

Source: R. van Beurden-Amkreutz, Exida

Mechanical Advantage: Benefits

Device requires no extraneous controls or devices in the control loop.

The control loop is kept as simple as possible

When the device is tested, all the actual components and controls stroke the ESD in the “real world” speed of operation.

Mechanical Advantage: Benefits

Cost Savings

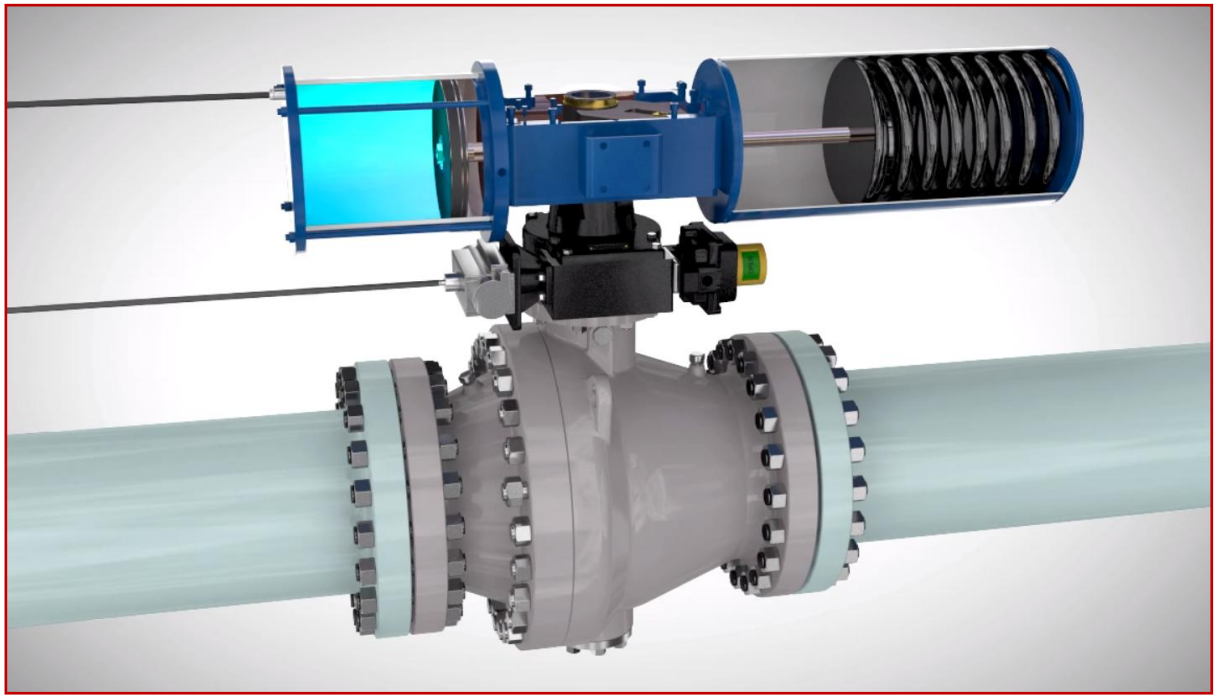
- Simpler control loop
- No additional power or wiring
- No instrumentation commissioning
- No calibration
- Minimal personnel training
- No Software / No Software Training
- No Programmers
- Field Retrofit

Mechanical Advantage: Benefits

Reliable and Viable

- Metal-to-metal:
  - Valve cannot travel past set point
  - Reduced Spurious Maintenance Alarms

- Limit Switches can provide status to control room
- Human Interface / Visual Inspection
- SIL Capable / FMEDA



Remote Automation of Mechanical Partial Stroke Test Devices

Mike Mitchell
Cameron Flow Control / DYNATORQUE
Valve World – 24 September 2009

Mechanical PST During ESD

And if we have time….

Mechanical PST During ESD

What happens if my system needs to ESD during Mechanical PST?

Mechanical PST During ESD

What is the *probability* of ESD occurrence when the mechanical device is engaged?

What is the *likelihood* of ESD occurrence at the time of PST? (When is an ESD event likely to occur?)

Mechanical PST During ESD

First: what is the *probability* of ESD occurrence when the mechanical device is engaged?

Mechanical PST During ESD

Assume PST 1x per 4 weeks
5 minutes per test

$$\frac{\text{5 minutes}}{\text{40,320 minutes}}$$

Available 99.99% of the time

Mechanical PST During ESD

D-Stop 1.36E-04 **3.85E-05**

Reality: PST 1x per 90 Days
5 minutes per test

$$\frac{\text{5 minutes}}{\text{129,600 minutes}}$$

Available 99.9999615% of the time

Mechanical PST During ESD

Second: what is the *likelihood* of ESD occurrence at the time of PST?

(Or: when is an ESD event likely to occur?)

Mechanical PST During ESD

When do Accidents Happen?

Worker activities associated with fire and explosion deaths in industrial workplaces:

- Repair and maintenance activities 28%
- Welding 24 %
- Construction / Installation 13%

Welding accounted for 1/3 of all incidents

Mechanical PST During ESD

When do Accidents Happen?

"Non-normal" times:

- Bad weather
- Plant start up
- Plant shut downs
- Maintenance turnarounds
- Construction

Mechanical PST During ESD

When do Accidents Happen?

Conclusion: ESD will most likely occur during times we would NOT *schedule* a PST.

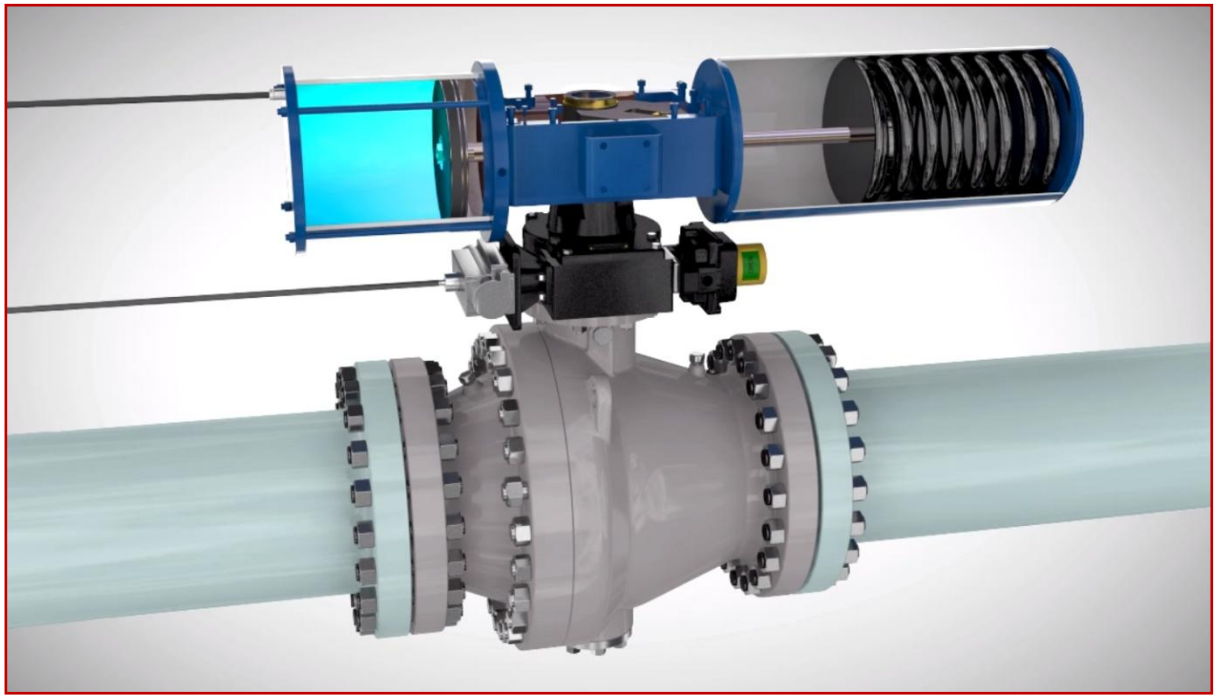
Manual PST will be scheduled during "normal" or "routine" plant operations when time, weather and other conditions allow for such routine maintenance activities to occur.

Mechanical PST During ESD

When do Accidents Happen?

99.99 % **99.9999615%**

Is it statistically significant that an ESD will occur during non-availability *and* during the most *unlikely* conditions to perform a mechanical Partial Stroke Test?



Reconsidering Mechanical Devices for Partial Stroke Valve Testing

Mike Mitchell
Cameron Flow Control / DYNATORQUE

Mary Kay O'Connor Process Safety Center International Symposium : October 26-27, 2010