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 ($\text{PFD}_{\text{AVG}}$) between established full stroke test intervals

- or -

Increase time between full stroke test intervals while maintaining or lowering the $\text{PFD}_{\text{AVG}}$. 
$PFD_{AVG}$ increases with time.
Partial and Full Stroke tests decrease $\text{PFD}_{\text{AVG}}$
Safety Integrity Levels (SIL) reflect relative levels of risk reduction

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

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

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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
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
Mechanical Partial Stroke Test Device

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

Pilot Actuator

Limit Switch
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.
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 maintenence
Mechanical Aspects of Electronic Systems
Mechanical Advantage: Metal to Metal Safety

Device fully “engaged”
Safety Integrity Levels (SIL) reflect relative levels of risk reduction

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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 $\text{PFD}_{\text{AVG}}$ 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 $PFD_{AVG} \quad 1.36E-04$

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

Source: R. van Beurden-Amkreutz, Exida
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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?)
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

5 minutes
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

\[
\frac{5 \text{ minutes}}{129,600 \text{ minutes}}
\]

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?)
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
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.
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?
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