HIPPS the world of safety integrity

Sep 26, 2011

Presented by
FCT/Biffi Team

High Integrity Pressure Protection System

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- What is it?
- Why and where is it used?
- SIL
- Final elements
- Partial stroke testing
- Applications
- Actuation & Controls
- Solutions provider

Accidents happen

Cannot exclude human factor

What is HIPPS?

HIPPS

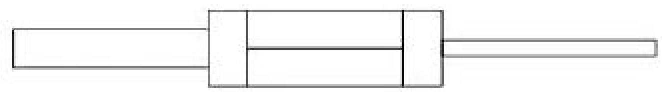
- A High Integrity Pressure Protection System (**HIPPS**) is a safety instrumented system (SIS) applied to bring a plant or equipment into a safe condition on demand. It is required in cases where a process or machinery malfunction give rise to either:
  - Hazards for personnel
  - Adverse effect on environment
  - Equipment damage
  - Considerable economic loss

What is HIPPS ?

A **HIPPS** is a protection device/system

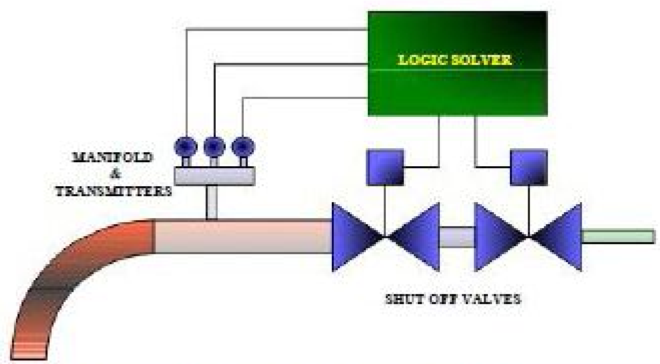
It acts like a fuse;

if the current is too high, the fuse blows



If the pressure is too high,

the valves close.



The system behind it is safe!

What is HIPPS?

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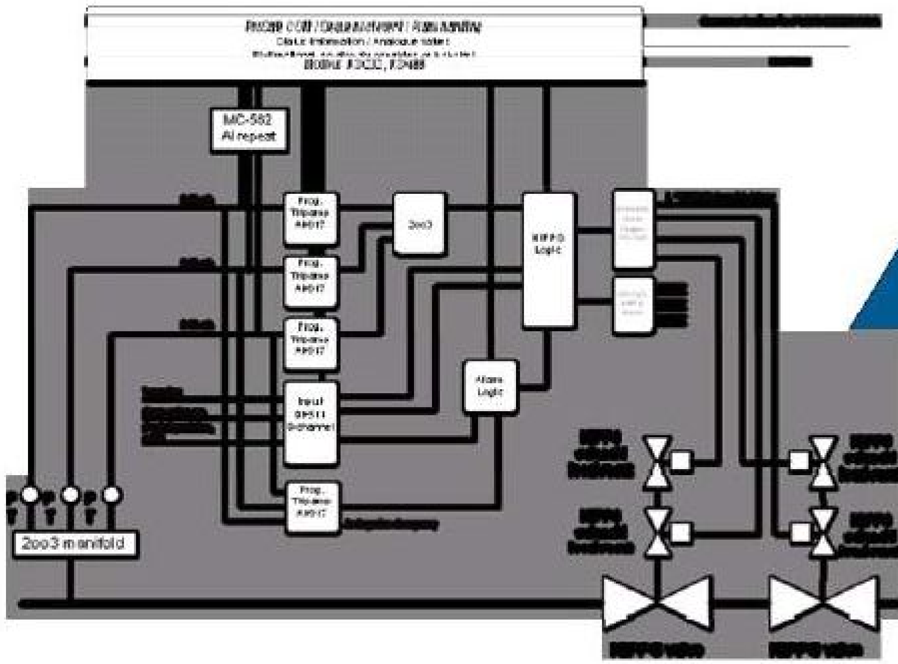
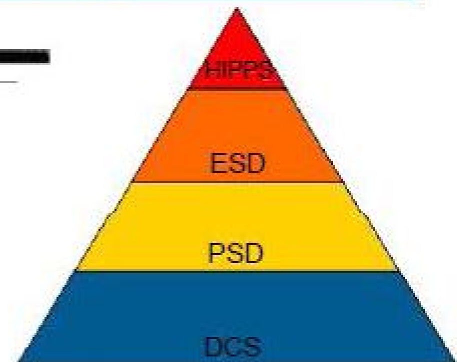
Fail Safe Instrument Safeguarding System with a high **RELIABILITY** for the isolation of the pressure source from the downstream equipment in case of overpressure, which is the **LAST REQUIRED LEVEL OF DEFENSE**

HIPPS are **independent** and **reliable** systems, that shall operate on a higher Level than Process Shut Down and Emergency Shut Down.

What is HIPPS ?

HIPPS, the last line of defense





What is HIPPS ?

- 1. A very RELIABLE ***Fail Safe System***, combining mechanical and electrical (SOV) redundant components, independently able to QUICKLY shut off the plant in case of overpressure
- 2. Health& Environment (HES).
- 3. DELETE / REDUCE ***flare capacity system*** for situations like :
  - Environmental regulations limit the use of conventional relief systems.
  - The economic viability of a development needs improvement.
  - Extreme high-pressures, or flow rates are processed
  - The risk profile of the plant must be further reduced.
- 4. High INTEGRITY DESIGN Level for HIPPS Valves in ***critical operating applications***
- 5. To REDUCE and MINIMIZE ***pressure rise risks*** for a complete installation,

→ **COST SAVINGS**

What is HIPPS ?

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What are Shut off Isolation Unit (Hipps Valve) main requirements ?

1. System comply with SIL Level requirement (system PFD analysis)
2. Designed for continuous operation (Fully Open or closed position)
3. Quick operation on demand
4. Highest possible availability level
5. Tight shut off / High shut off integrity (In all probable circumstances)
6. Meet process requirements (corrosion, temp., Location, ..)
7. Easy to operate and Maintain (plant shut down)
8. No Possible Override (or unexpected operation)
9. High flow rate (Generally on main line)
10. Piggable for pipeline
11. Do not require external power for the safe state (Fail safe).
12. In line checking (To detect hidden faults-dangerous undetected)

Why is it used?

Conventional pressure relief

- The simplest way of dealing with overpressure situations is allow a relief valve to vent to the atmosphere or into a flare. In several cases such venting cannot be used.

  - If flow rates through relief valve would be excessive
  - If toxic gases would be released
  - If there would be a significant environmental impact
  - If plant has non-flaring operational objectives
  - If it is desirable to minimize loss of product
  - If operating company has other requirements (strategic protection of major production installations)

- The alternative to a mechanical pressure relief valve is a HIPPS designed for SIL-3 or SIL-4

Safety Integrity Level

What is SIL

- SIL (safety integrity level) is essentially a measure of the system performance in terms of probability of failure on demand (PFD).
- Risk = probability X consequences
- A HAZOP (hazard and operability) team performs a study of what can go wrong and identifies which system will create the highest level of risk and determines the impact of the failure (consequence)
- Risk tolerances level are set by the plant owner

Safety Integrity Level	Safety Availability	Risk Reduction Factor	Probability of Failure on Demand
SIL 4	>99,99%	100,000 to 10,000	10_{-5} to 10_{-4}
SIL 3	99,9 - 99,99%	10,000 to 1,000	10_{-4} to 10_{-3}
SIL 2	99 - 99,9%	1,000 to 100	10_{-3} to 10_{-2}
SIL 1	90 - 99%	100 to 10	10_{-2} to 10_{-1}

Safety Integrity Levels

Safety Integrity Level

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SIL standards applied

- In most countries, safety requirements for man, equipment and environment follow state of the art technology as a binding and legal requirement.
- Standard is IEC 61508 (Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems)

  specifies both the risk assessment and the measures to be taken in the design of safety functions consisting of sensor, logic solver and actuator

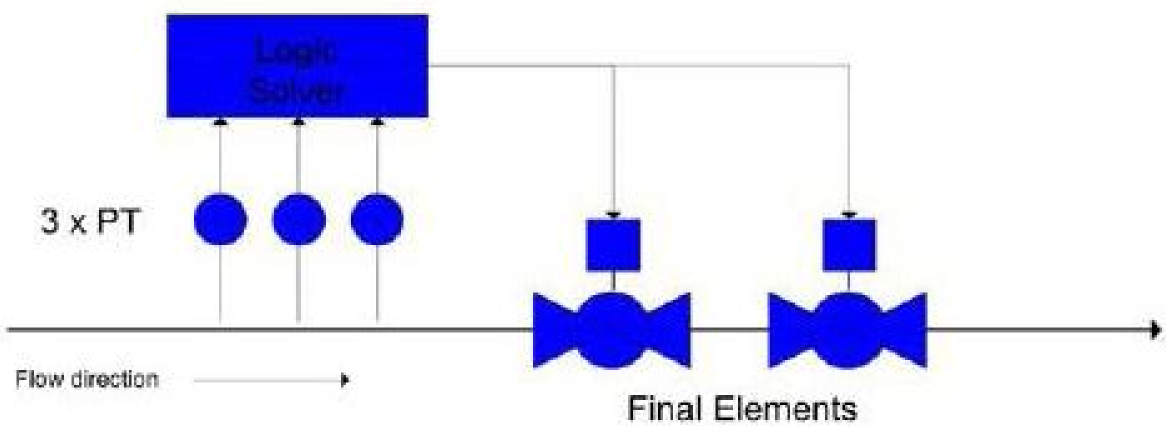
- Standard IEC 61511 (Functional safety - Safety instrumented systems for the process industry sector) defines selection criteria for components of safety functions, like prior use demonstration of sensors, actuators and valves.

Relationship between IEC 61508 and IEC 61511

HIPPS Final elements

A HIPP System

- A HIPPS is a complete functional loop and consisting of:
  - Sensors or initiators that detect the pressure
  - Logic solver processing the input from the sensors to an output to the final elements
  - Final elements performing the corrective actions by bringing the process to a safe state.



HIPPS Final elements

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Tyco's portfolio

- Products are not SIL rated.
  Therefore we should never say our products are SIL 3
- Instead we should use the nomenclature
  our products are suitable for a SIL 3 environment

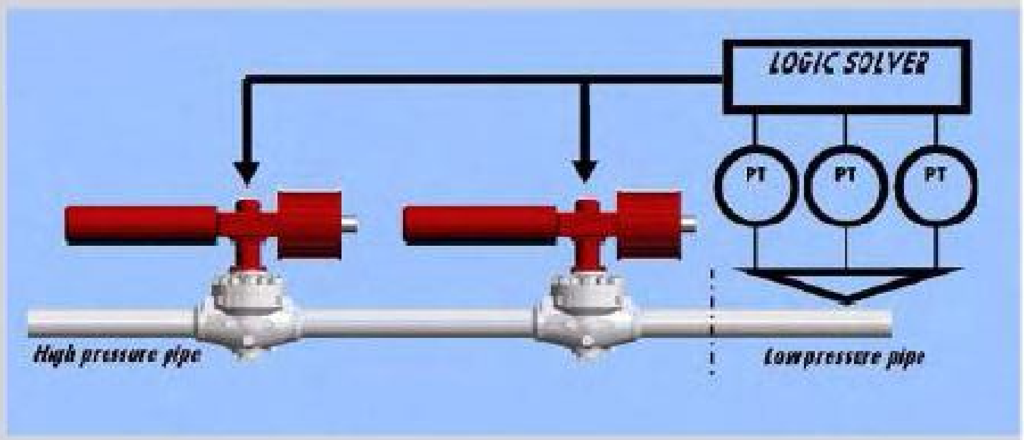
- Tyco has the following brands manufacturing product suitable for SIL

• FCT	- trunnion mounted ball valves
• KTM	- ball valves and actuators
• Vanessa	- triple offset valves
• Biffi	- actuators pneumatic or hydraulic and electric PST device
• AGI	- manifold (being development)

Products are suitable for a SIL 3 environment

FCT - FLOW CONTROL TECHNOLOGIES

HIPPS BALL VALVE DESIGN SUGGESTIONS



FCT HIPPS BALL VALVES

The highest level of safety and reliability


RWTUV

Certificate

Flow Control Technologies (FCT)

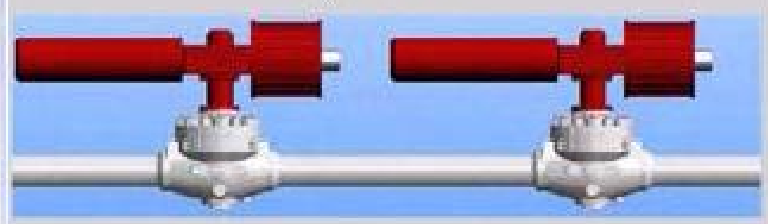
Split Body Ball Valves – Top Entry Ball Valves

FCT Split body and Top Entry

Ball Valves comply with:

SIL 3

SIL 4



FCT HIPPS BALL VALVES

HIPPS VALVE WORKING CONDITIONS

- Valve remains open most of the time
- Quick closing on demand
- Ensure pipe shut-off

CONSEQUENCE ON A VALVE STANDARD DESIGN WITH SOFT INSERT

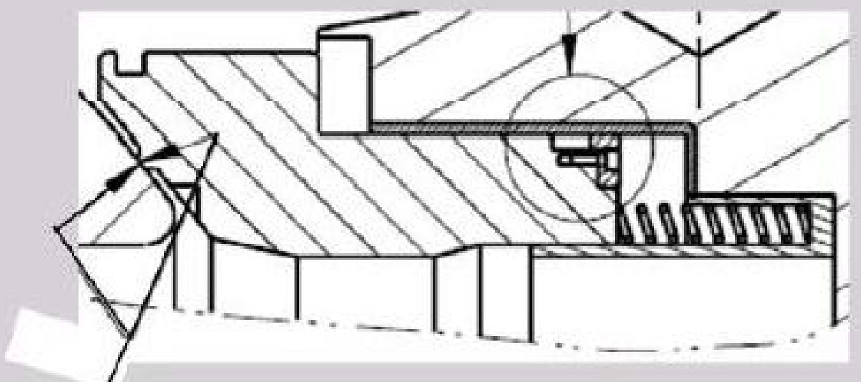
- Ball " Sticking" on Seats
- Sluggish Response

Failure to deliver a full stroke and achieve pipe shut-off

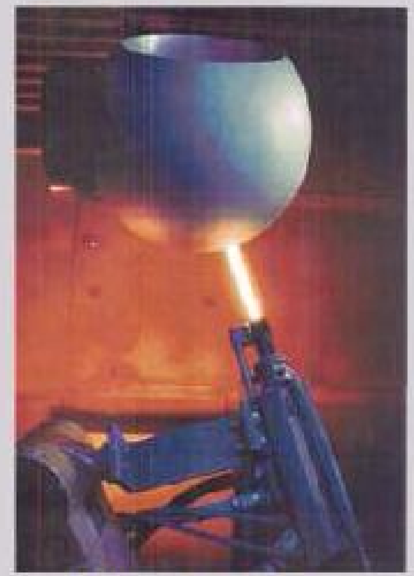
FCT HIPPS BALL VALVES

METAL-TO-METAL SEATING prevents from:

- Erosion on the seats contact surface
- Ball " sticking" on seats



150μm Tungsten Carbide Coating on both seat and ball contact surfaces



1050 Hv Hardness
Harder than sand

Excellent Wear Resistance
High Mechanical Bond strength
HVOF Process

FCT HIPPS BALL VALVES

HIPPS VALVE WORKING CONDITIONS

- Valve remains open most of the time
- Quick closing on demand
- Ensure pipe shut-off

CONSEQUENCE ON A VALVE STANDARD DESIGN

- Seals failure
- Non performance of the sealing and friction areas

Failure to deliver a full stroke and achieve pipe shut-off

FCT HIPPS BALL VALVES

MAIN SEALS FAILURE :

- Explosive Decompression
- Chemical incompatibility between seals and medium
- Corrosion of the sealing surfaces

HOW DOES FCT PREVENT FROM SEALS FAILURE?

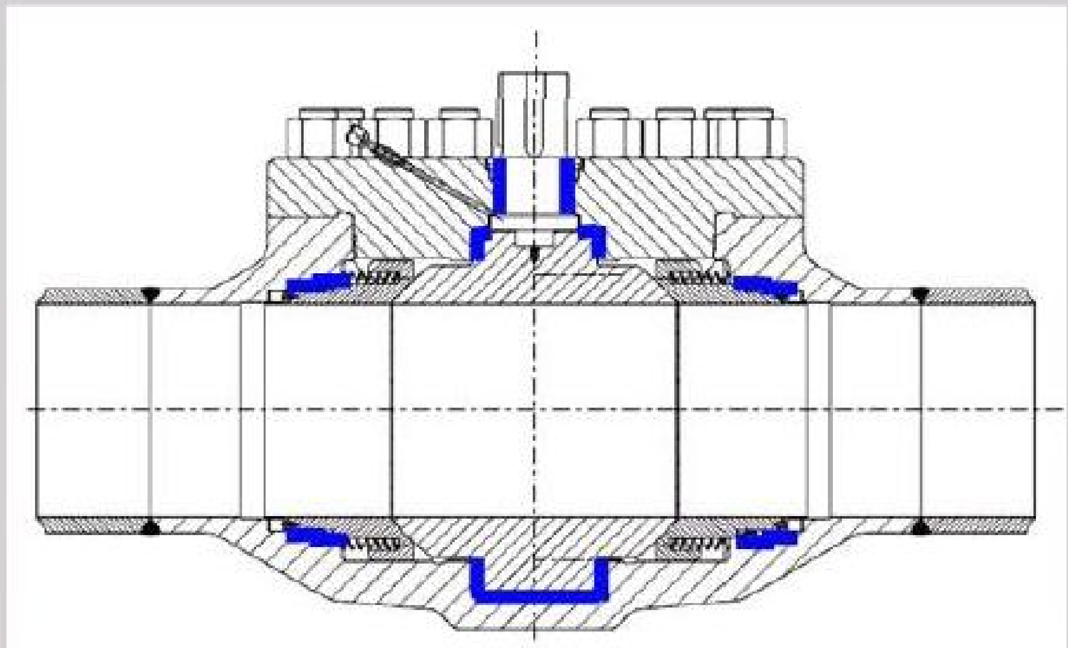
Only PTFE lip seals are supplied

- PTFE Lip-seals withstand high pressures
- Avoid any risk of failure due to explosive decompression
- PTFE is chemically inert with the whole agressive mediums

FCT HIPPS BALL VALVES

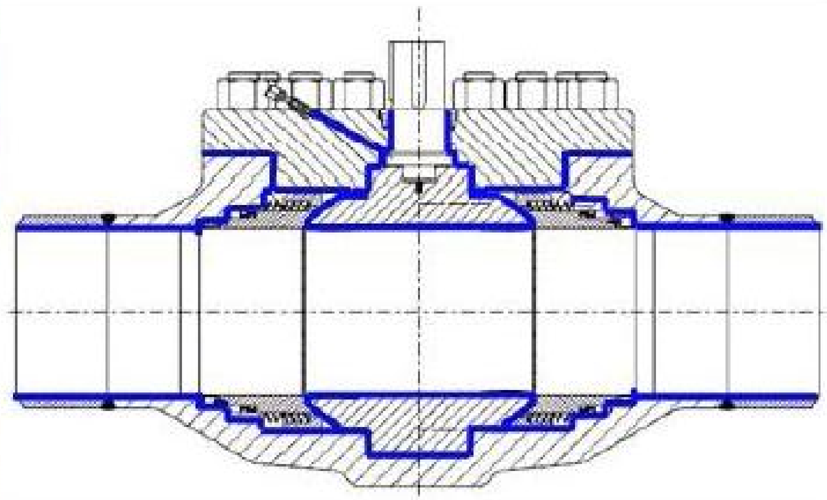
As sealing performance also depends on sealing areas, FCT recommends 3mm thickness **Weld overlay** (316L SS, Inconel® Alloy 625) shall be applied on **all dynamic sealing and friction areas** to enhance the wear and corrosion resistance.

Weld overlays on sealing areas prevent from internal leakage due to corrosion.



FCT HIPPS BALL VALVES

Full Cladding on all wetted parts (316 SS, Inconel 625…) for protection against agressive mediums or Cost saving against Body/ball made from full CRA



FCT HIPPS BALL VALVES

HIPPS VALVE WORKING CONDITIONS

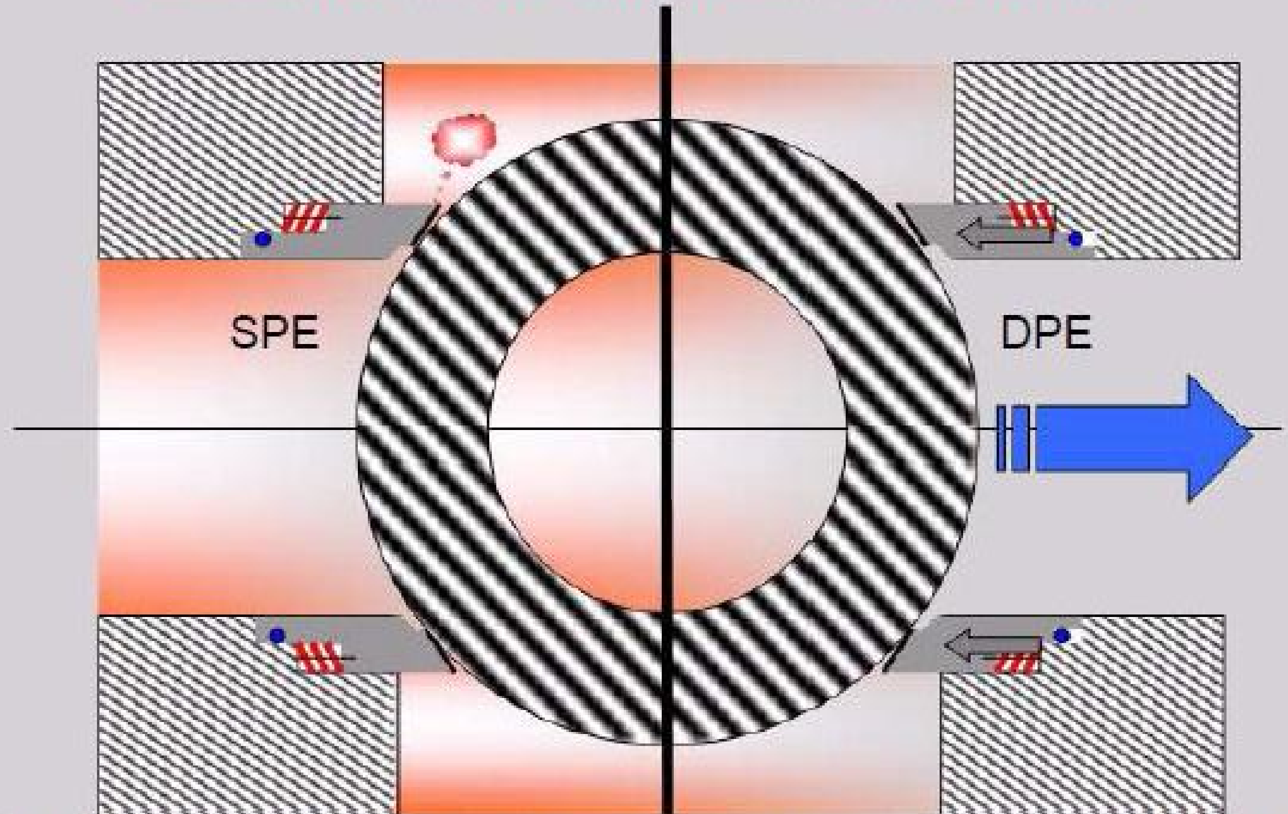
- Valve remains open most of the time
- Quick closing on demand
- Ensure pipe shut-off

HOW DOES FCT ENSURE DOWNSTREAM EQUIPMENT PROTECTION ?

- By combining existing seat designs → double seating barrier

SPE / DPE

Redundancy on shut-off barrier (downstream protection)

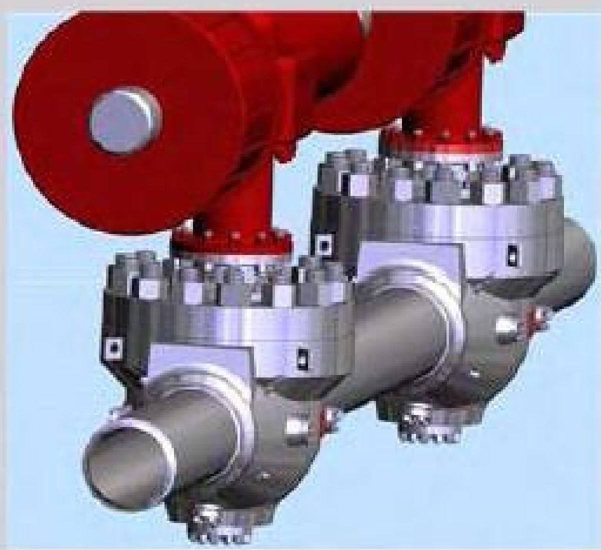


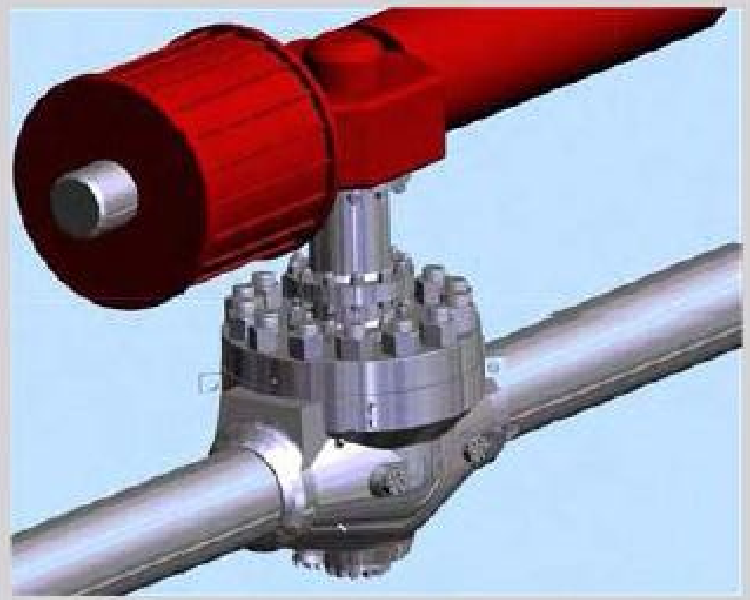
- Tightness through the 2 seats (Downstream seat acts as a second barrier)
- Self-relief of the body cavity in case of overpressure through SPE seat

FCT HIPPS BALL VALVES

FCT recommend using TOP ENTRY design which presents additional advantages:

- Possibility of in line maintenace (cost saving)
- High strengh body design which gives better behaviour in front of abnormal pipe loadings (bending moment, vibrations, axial forces, water hammer...)
- Best performance obtained during FEA and qualification test
- Large stem sizing allowing high resistance to actuator showing high torque values





FCT HIPPS BALL VALVES- RECOMMENDED DESIGN FEATURES

FCT recommends the TOP ENTRY body for HIPPS application:

- Top Entry design has better resistance against piping loads → the quick closing (2sec) will generate a huge water hammer on liquid service

  The top entry design also allows in line maintenance

- Tungsten Carbide coating on both seats and ball → extremely hard, prevents seat seal damage and erosion

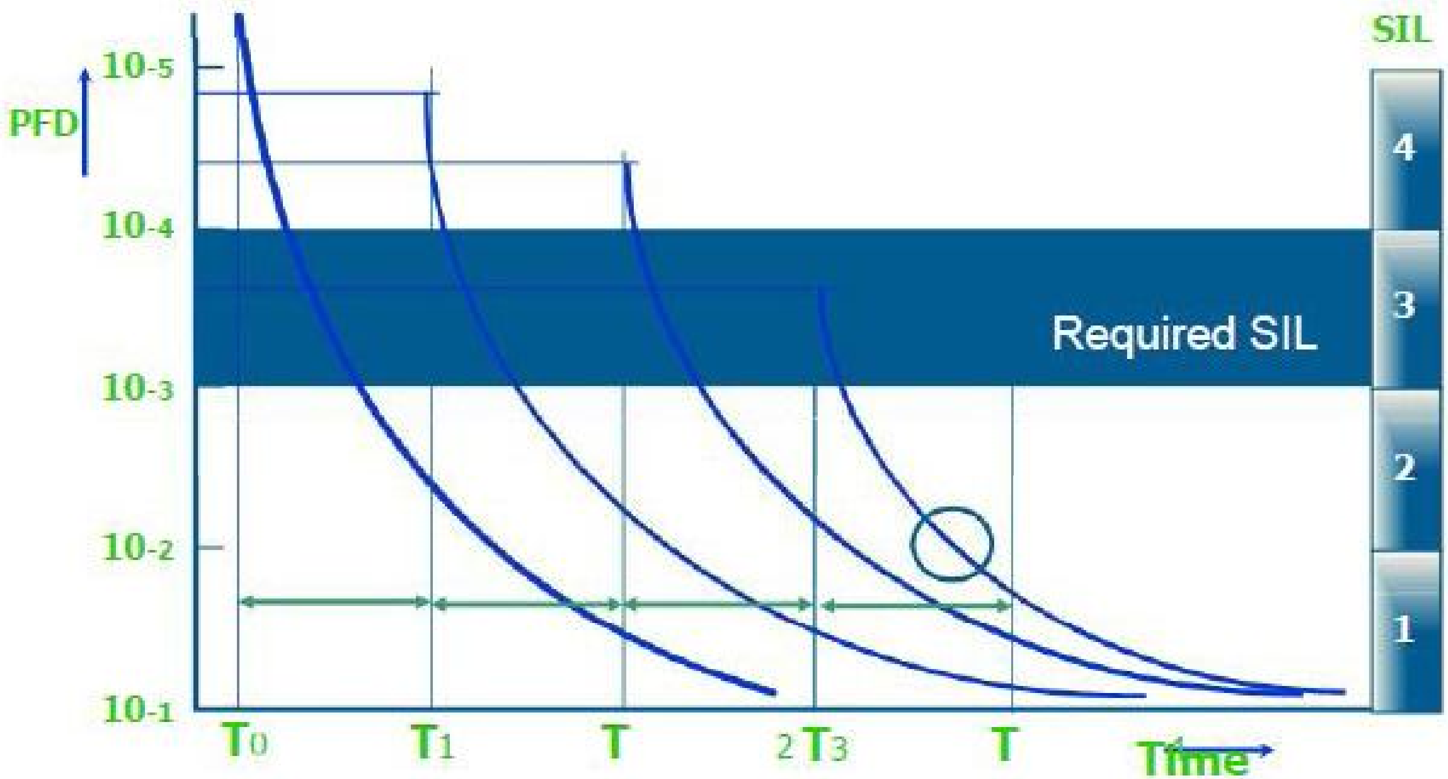
- DPE seat on downstream side to give redundancy on shut off barrier

- Inconel 625 overlay on stem, seat pockets and friction areas for CS valve → to prevent leakage due to corrosion

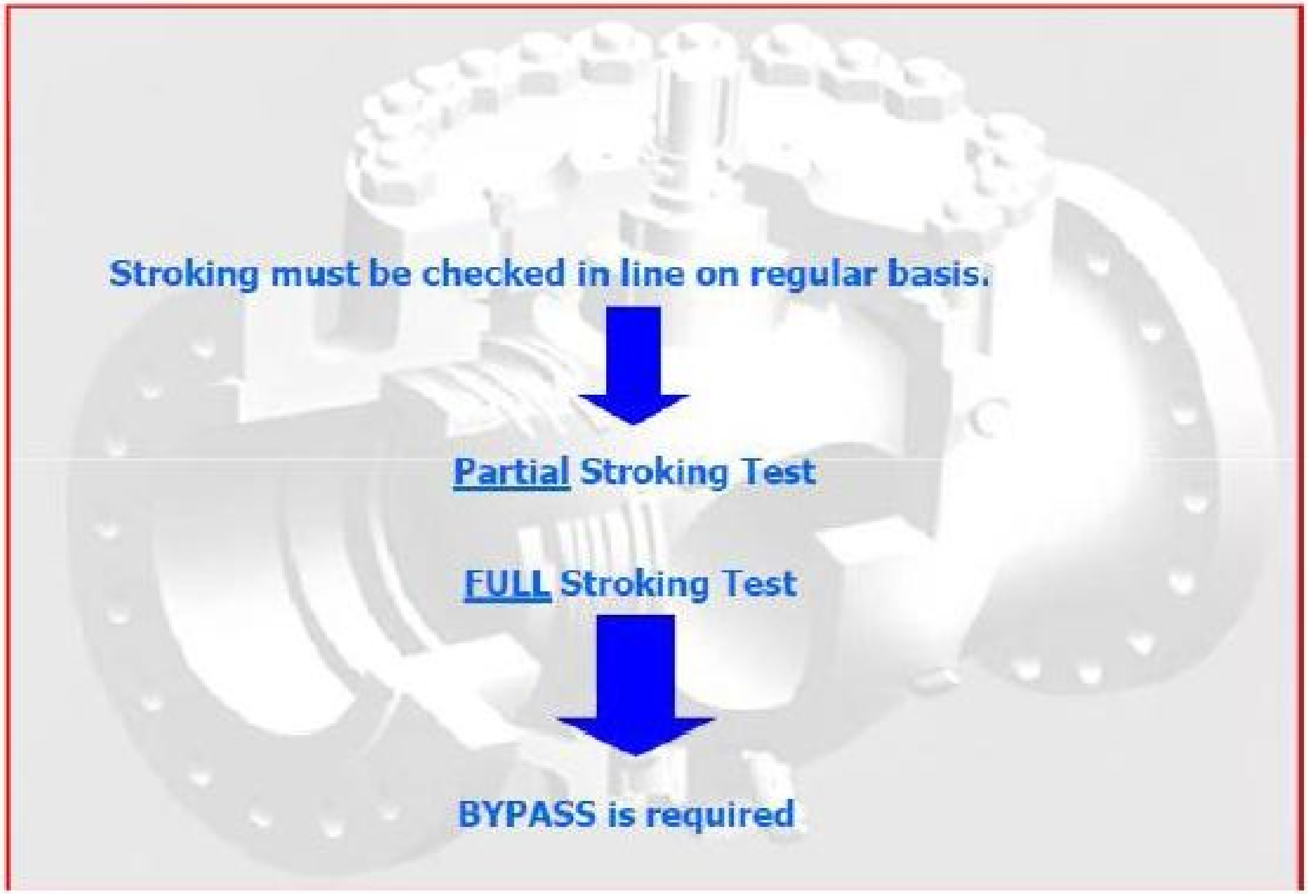
- PTFE lip-seals → to prevent leakage due to bad medium compatibility or Explosive decompression

Partial Stroke Testing

- SIL degrades in time
- PST upgrades SIL



Partial Stroke Testing



Partial Stroke Testing

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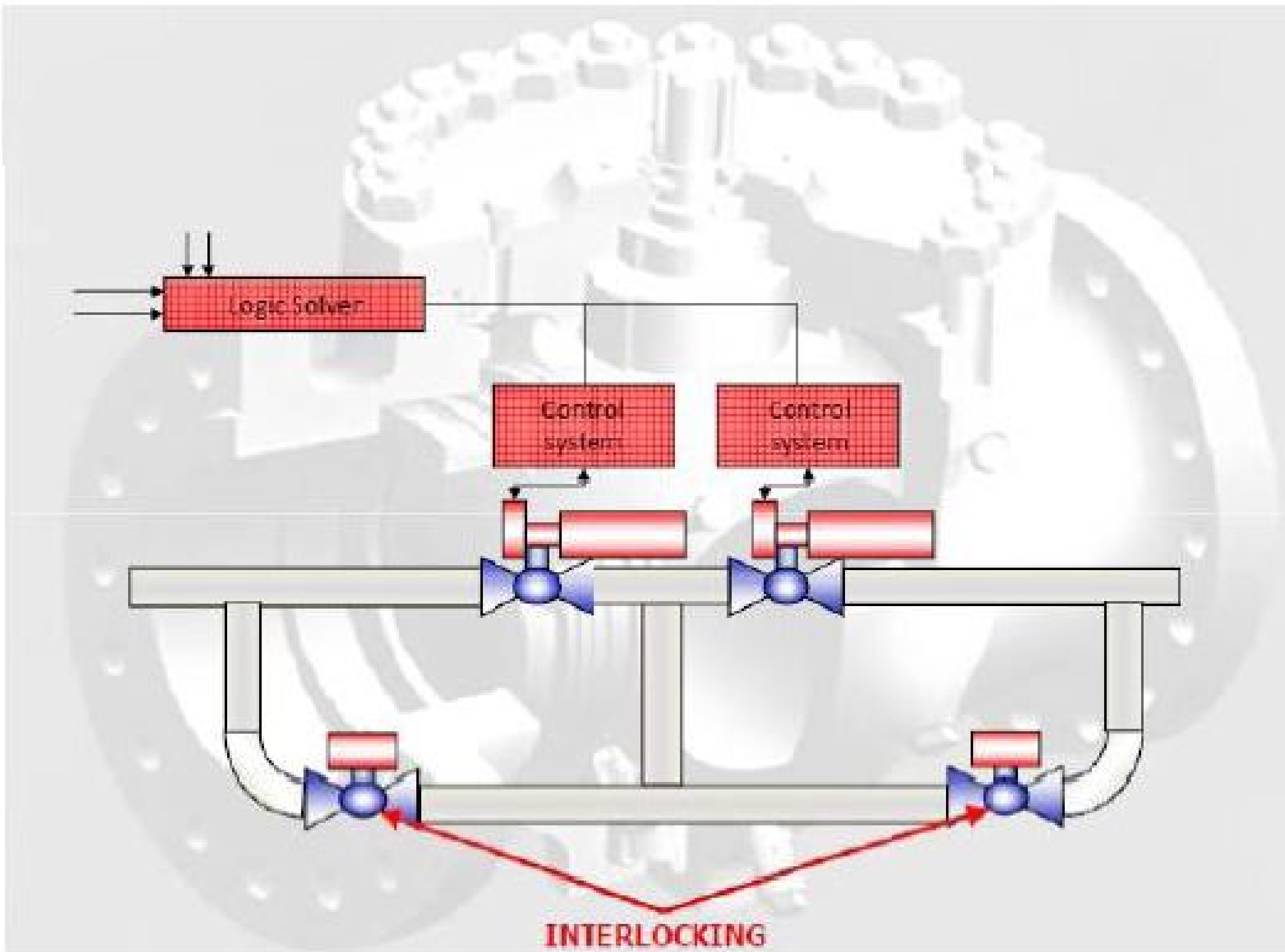
Benefits of the Partial Stroke Test:

- Valve is closed by 15° . No shut down of process
- Dangerous failures detected
  - Valve stuck
  - Sluggish Response
  - Jamming or damage of the actuator
  - Clogging and damage of control system pneumatic piping system

- Valve is tested at shorter intervals than with full stroke testing
- Increasing the proof test frequency consequently lowers the PFD average

- Partial Stroke Testing only should be applied in addition to Full Stroke Testing.
- Only FST provide a full diagnostic coverage

Partial Stroke Testing



Tyco products suitable for SIL 3 environment

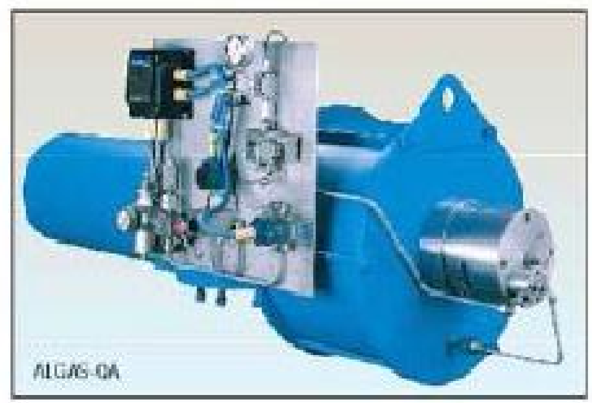
Vanessa TOV

KTM ball valve + actuator

Biffi electr. PST device

FCT ball valve

Biffi pneumatic actuator and control panel



Actuation & controls

OLGAS-QA

ALGAS-QA

Actuation & controls

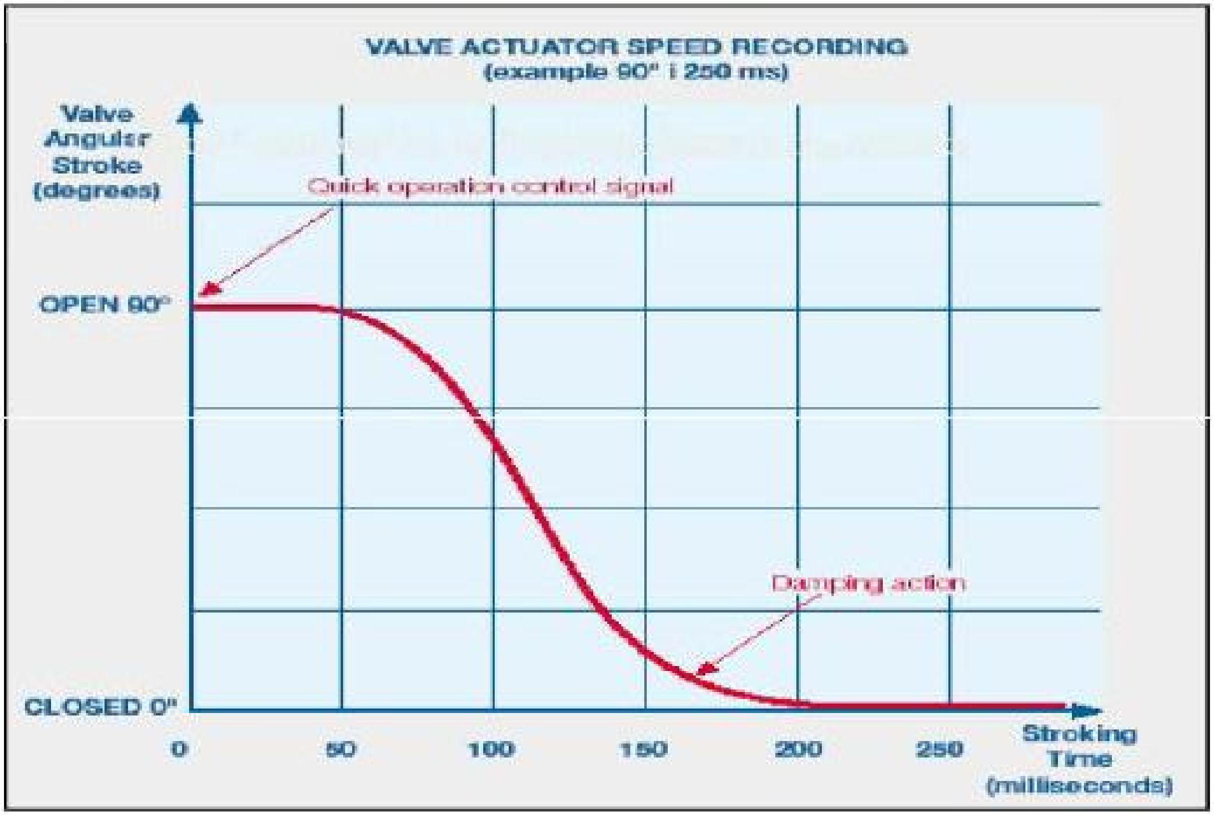
Direct coupling on valve stem (No use of coupling)

- Accurate selection of control system components
  - Flow capacity
  - Materials
  - Reliability: Vibration, Temperature, Ambient conditions
- Redundancy of components
- Damping system to reduce gradually the stroking speed

CLGAS-QA

Actuation & controls

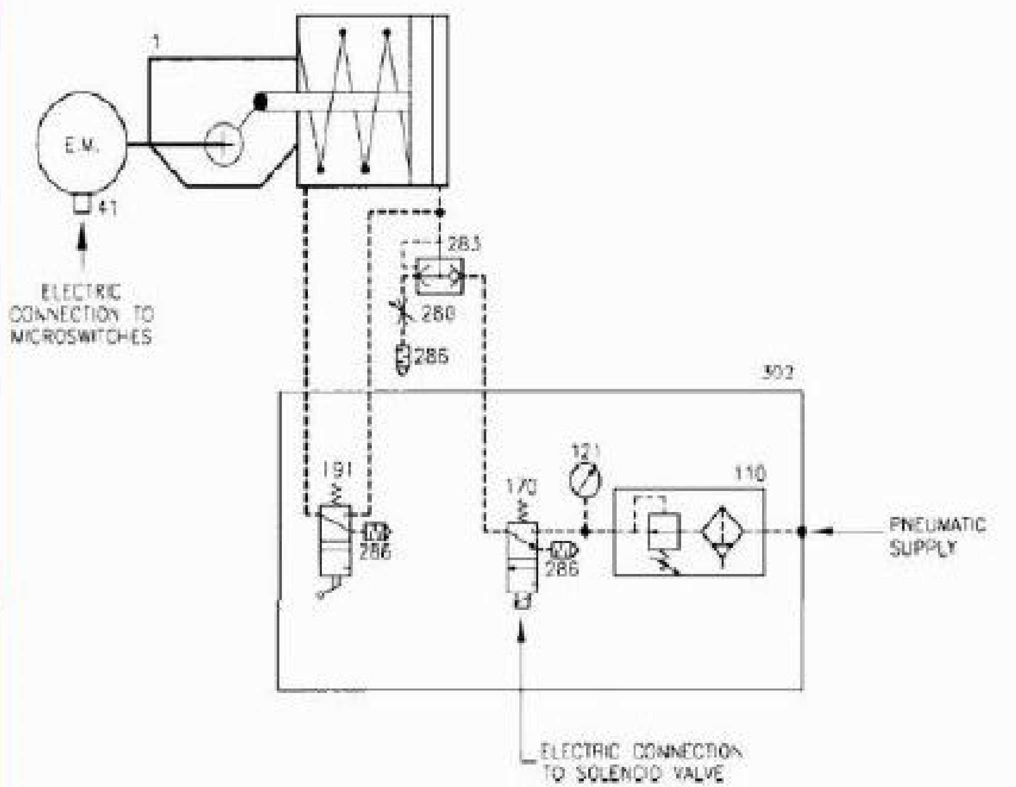
ACTUATOR Damping effect in the last part of the stroke



Typical Functional Test for Pneumatic Single Acting Actuator

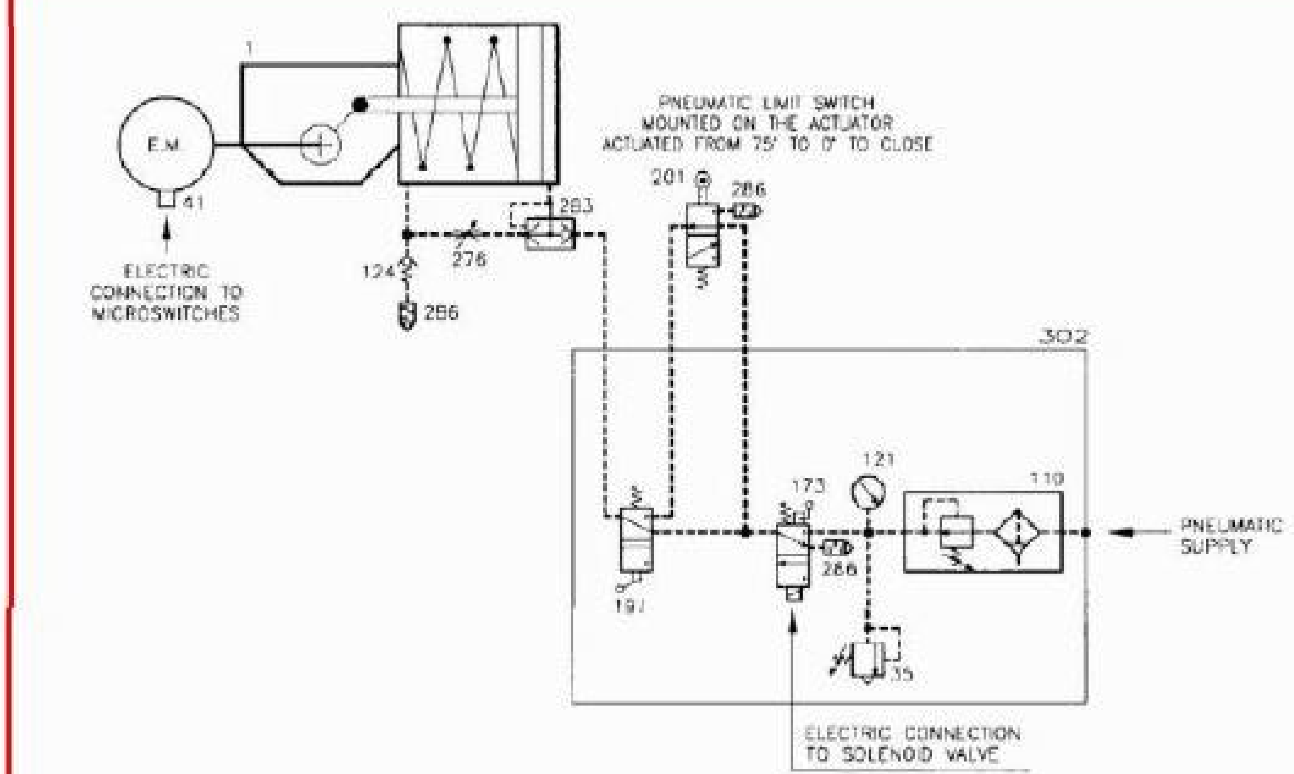
- Spring Inspections
- Cylinder leak test
- Piston Leak test
- Main casing pressure test
- Installation Settings
- Actuator Cycling tests
- Functional tests Including opening speed checking
- Speed for Closing under spring load
- Leakage test (Duration)
- Torque Tests
- Performance test at 4 Barg / 7 Barg
- Operating under load test
- Performance after Spring Test
- Torque tests & compressed spring test
- Repeat pressure test
- Stall test (At max output)
- Post inspection & assessment
- Cleaning

Pneumatic control with local partial stroking operation

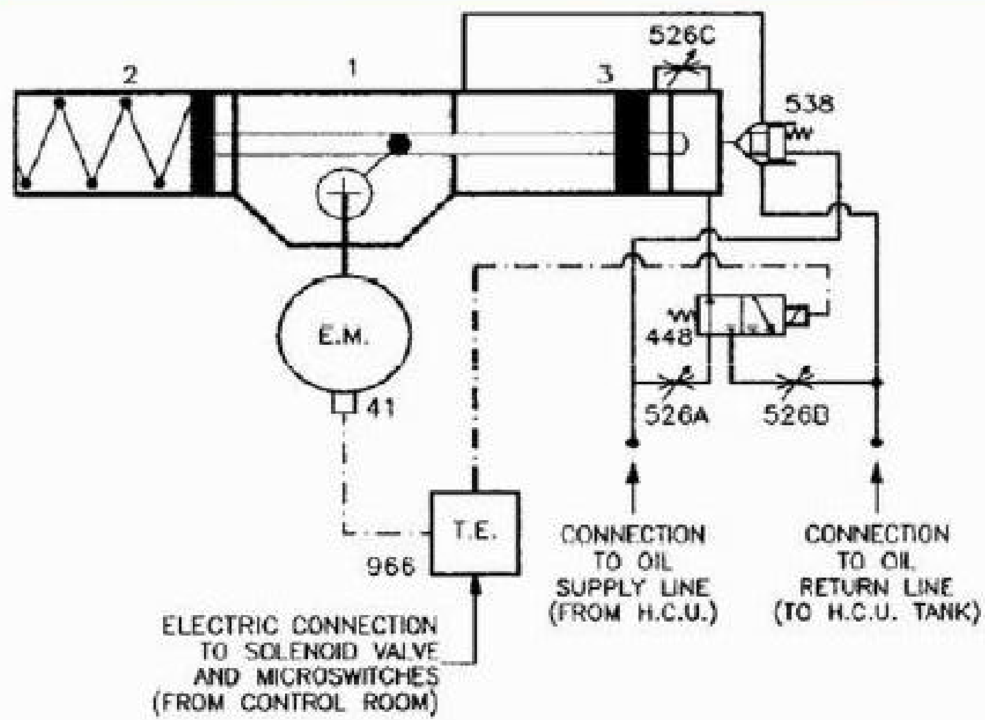


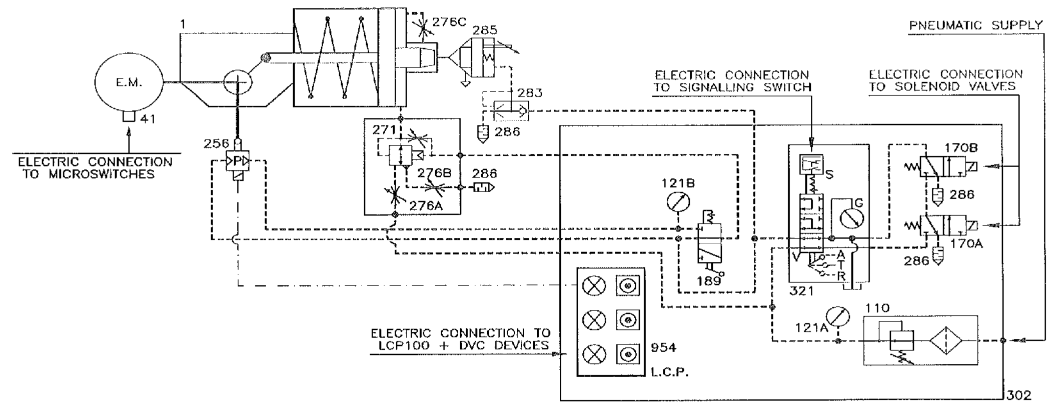
Actuation & controls

Pneumatic control with local partial stroking operation and automatic re-opening after 15 degrees rotation by pneumatic limit switch



Hydraulic control for Quick Closing actuator
Remote partial closing operation by solenoid valve





ELECTRIC REMOTE CONTROL TO OPEN
ENERGIZE PERMANENTLY BOTH SOLENOID VALVES 170. THE OPENING TIME IS ADJUSTABLE BY THE FLOW REGULATOR 276A.
NOTE: THE DEVICE 321 MUST BE IN "A" POSITION (AS SHOWN) TO ALLOW THE ELECTRIC REMOTE CONTROL.

ELECTRIC REMOTE CONTROL TO CLOSE
DE-ENERGIZE AT LEAST ONE OF SOLENOID VALVES 170. THE CLOSING TIME IS ADJUSTABLE BY THE SETTING OF VALVE 285 AND THE DAMPING EFFECT IS ADJUSTABLE BY THE FLOW REGULATOR 276C.
NOTE: THE DEVICE 321 MUST BE IN "A" POSITION (AS SHOWN) TO ALLOW THE ELECTRIC REMOTE CONTROL.

PARTIAL CLOSURE TEST
OPERATE THE VALVE 189 TO "TEST" POSITION. START THE PARTIAL CLOSURE TEST BY SENDING THE PROPER SIGNAL TO THE DEVICE 256. THE ACTUATOR INCHES TOWARD CLOSING DEPENDING ON VALVEGUARD SETTING AND THEN RETURNS TO FULLY OPEN POSITION.
NOTE: THE VALVE 189 MUST BE IN "AUTOMATIC" POSITION TO PREVENT THE PST OPERATION.
THE ELECTRIC REMOTE CONTROL TO CLOSE OVERRIDES THE PST OPERATION.

LOCAL CONTROL
BY LOCALLY OPERATING THE LCP100 954 THE OPENING, CLOSING AND PST OPERATIONS CAN BE PERFORMED.
NOTE: THE ELECTRIC REMOTE CONTROL TO CLOSE OVERRIDES ANY LOCAL OPERATION.

SOLENOID VALVE TEST
OPERATE THE DEVICE 321 IN "T" POSITION. THE SUPPLY, THE OUTLET LINE TO ACTUATOR AND THE INLET LINE OF SOLENOID VALVES ARE CONNECTED, THE OUTLET OF SOLENOID VALVES 170 IS CLOSED AND THE ACTUATOR IS LOCKED IN OPEN POSITION. THE SOLENOID VALVES 170 CAN BE DE-ENERGIZED, THE GOOD WORK OF SOLENOID VALVES 170 CAN BE CHECKED BY THE PRESSURE GAUGE 321G.
NOTE: THE POSITION OF DEVICE 321 IS SIGNALLED BY THE SWITCH 321S.

SOLENOID VALVE MAINTENANCE
OPERATE THE DEVICE 321 IN "R" POSITION. THE SUPPLY AND OUTLET LINE TO ACTUATOR ARE CONNECTED, THE INLET AND OUTLET OF SOLENOID VALVES 170 ARE CLOSED AND THE ACTUATOR IS LOCKED IN OPEN POSITION. THE SOLENOID VALVES 170 CAN BE DISCONNECTED FOR MAINTENANCE.
NOTE: THE POSITION OF DEVICE 321 IS SIGNALLED BY THE SWITCH 321S.

NOTE:
THE DIAGRAM IS DRAWN WITH SOLENOID VALVE COIL NOT ENERGIZED.

1	SINGLE ACTING SPRING RETURN PNEUMATIC ACTUATOR
41	ELECTRIC MICROSWITCHES
110	FILTER REGULATOR
121	PRESSURE GAUGE
170	3/2 N.C. DIRECT ACTING SOLENOID VALVE
189	3/2 HAND OPERATED VALVE
256	PARTIAL STROKING TEST DEVICE (DVC 6030)
271	PNEUMATIC BOOSTER + BY-PASS
276	BIDIRECTIONAL FLOW REGULATOR (ADJUSTABLE SETTING)
285	ADJUSTABLE QUICK EXHAUST VALVE WITH EXTERNAL PILOT
286	DUST EXCLUDER
302	PANEL
321	4/3 HAND OPERATED BY-PASS VALVE V - BY-PASS VALVE G - PRESSURE GAUGE S - SIGNALLING SWITCH
954	LCP 100 LOCAL CONTROL PANEL

PNEUMATIC CONNECTION ELECTRIC CONNECTION

Rev.	Date	By	Approved	Description

AutoCad 12.0 Path T:\TA BIFFI	SPRING TO CLOSE PNEUMATIC ACTUATOR -OPERATING DIAGRAM-	Drawing Number TPADA163
		File TPADA163 / Date 02/11/10
		By / Approved

Actuation & controls - Other products

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Astava manifold cabinet

ATC actuators

Yokogawa logic solver

HIPPS Applications

- HIPPS mainly in upstream and pipeline(including subsea)

- Compressors
- Turbine
- Pipelines
- Wellhead
- UGS

HIPPS Applications

EHAS actuators for HIPPS ball valves South Pars

HIPPS Applications

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2secs closing time with a 4.2 tons Ball

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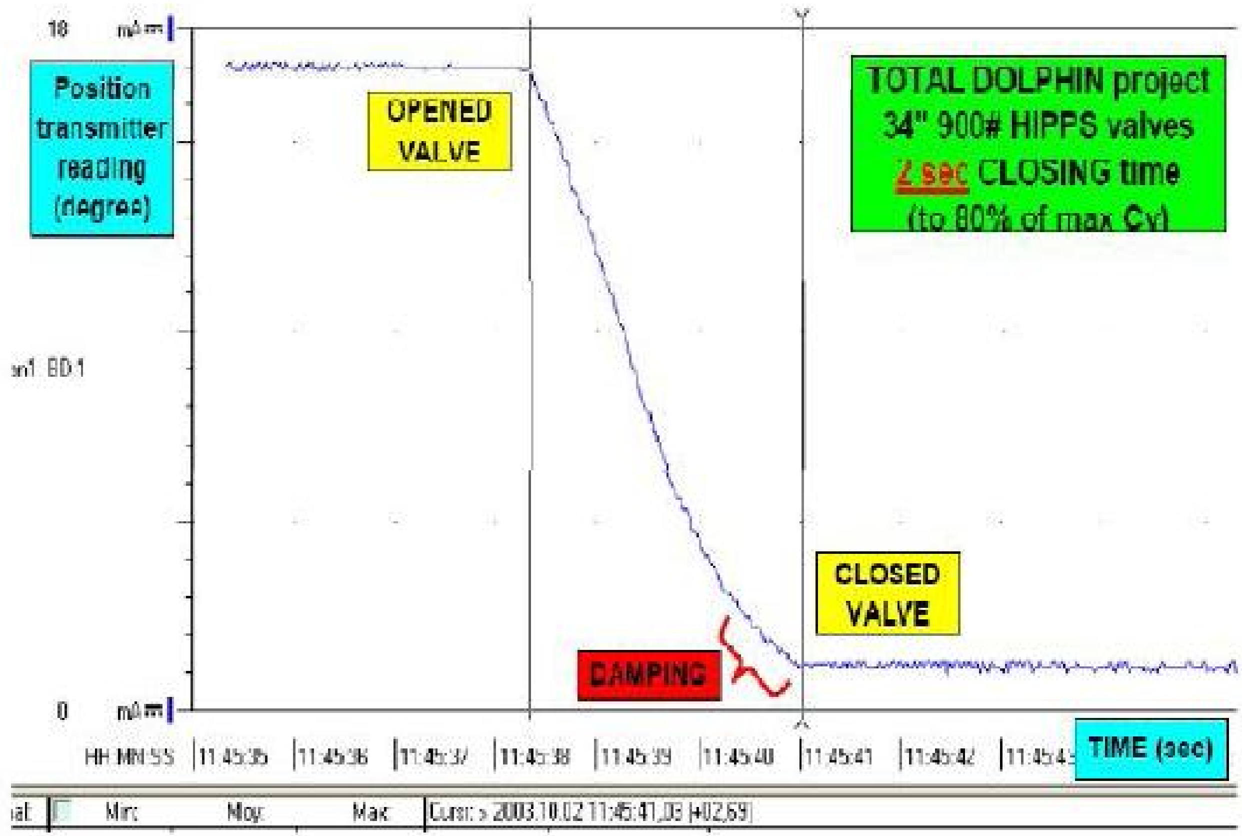
Flow Control
FCT

SPLIT BODY 3p 34" FB ANSI 900 Metal seated / Forged CS body
HIPPS valve 2 second closing time JGC / TOTAL - DOLPHIN Project

2secs closing time with a 4.2 tons ball



18
0
Position transmitter reading (degree)
OPENED VALVE
TOTAL DOLPHIN project
34" 900# HIPPS valves
2 sec CLOSING time
(to 80% of max Cv)
CLOSED VALVE
DAMPING
HH:MN:SS
11:45:35
11:45:36
11:45:37
11:45:38
11:45:39
11:45:40
11:45:41
11:45:42
TIME (sec)
Min
Moy
Max
Cursor 2003.10.02 11:45:41,03 (+02,69)

HIPPS Applications

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tyco FCT

TOP ENTRY 12" FB API 10000
HIPPS SIL3 - 2 second closing time
Metal/Metal - High yeld strength CS forged body
Technip Coflexip / BP Exploration SHAZ DENIZ Project

HIPPS Applications

tyco Flow Control FCT

HIPPS Applications

Electro-hydraulic EHAS actuator for large HIPPS ball valve GRANE Platform

Tyco solution provider

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Top entry, 24" FB, PN 305, 8 second closing time Body & ball CS + inconel 625 overlay

NPCC / ADMA-OPCO / Umm Shaif platform

Tyco solution provider

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- **Standard package**: ball valve (FCT) and actuator + control panel
  individual PFD value of each element

- **Extended package :** ball valve (FCT) and actuator + control panel
  Safety Analysis Report (SAR) for the actuated valve including:
    - PFD value of the final element (actuated valve) according to the project (means it is not an average value)
    - SIL based on calculated PFD and SFF values of the proposed system
    - TÜV third party validation of the actuated valve SAR

- **Full package : HIPPS** all final elements incl. logic solver, manifold, pressure transmitters etc.
    - TÜV validated Safety Analysis Report (SAR)

Valve (75%), A&C (15%), Logic Solver (10%).

Tyco Flow Control a solution provider

Tyco safety solution

- In the past Tyco provided components (final elements) for HIPPS to the end users or integrators.
- Today through FCT we provide the complete package including ball valve, actuator, manifold , pressure transmitters, logic solver etc. from one source.
- Only when the ball valve is FCT

SAR certified by Third party

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TÜV Industrie Service – *TÜV Rheinland Italia*
Test Laboratory for Pressure Equipment

TÜVRheinland®

Flow Control Technologies S.A.
2, Rue Sabanel
81160 Saint Juéry (France)

Assessment Report No.: **E 28107545**

SAR Assessment Report according to IEC 61508:1÷7:2000

Equipment: 1oo1 Final Element for Safety Instrumented System

Type: As defined in Flow Control Technologies Safety Analysis Report no. SAR-500961 Rev. A (Biffi Drawing Diagram N. SPAHA170) composed by:

- FCT Ball Valve
- Biffi Actuator Series ALGAS
- Panel control including:
  - Solenoid Valves (2)
  - Quick-Exhaust Valve
  - Pneumatic Valve
  - Dump Valve

Issue date: 2007-12-12

TÜV Rheinland Expert: Carlo Tarantola

BIFFI
tyco flow control

SAFETY ANALYSIS REPORT

DT Sample

Customer	VALVE MAKER
Order P.O.	123456 dated xx/xx/xx
Acknowledgements	BIFFI Ack. xx/xxxx
Project	OIL & GAS PROJECT
Final customer	FINAL USER LTD

0	xx/xx/xx	Issue document		
Rev	Date	Description	Prepared	Approved

ISA (D) PNID- 2011

Considerations for calculating a SIL Safety Instrumented Function (SIF)

GM INTERNATIONAL
TECHNOLOGY FOR SAFETY

Website: www.gmintsrl.com
Email: info@gmintsrl.com

Safety Integrity Levels IEC 61508

SIL Safety Integrity Level	**PFDavg** Average probability of failure on demand per year (low demand)	**(1-PFDavg)** Safety availability	**RRF** Risk Reduction Factor	**PFDavg** Average probability of failure on demand per hour (high demand)
SIL 4	**$\geq 10^{-5}$ to $< 10^{-4}$**	**99.99 to 99.999 %**	**100000 to 10000**	**$\geq 10^{-9}$ to $< 10^{-8}$**
SIL 3	**$\geq 10^{-4}$ to $< 10^{-3}$**	**99.9 to 99.99 %**	**10000 to 1000**	**$\geq 10^{-8}$ to $< 10^{-7}$**
SIL 2	**$\geq 10^{-3}$ to $< 10^{-2}$**	**99 to 99.9 %**	**1000 to 100**	**$\geq 10^{-7}$ to $< 10^{-6}$**
SIL 1	**$\geq 10^{-2}$ to $< 10^{-1}$**	**90 to 99 %**	**100 to 10**	**$\geq 10^{-6}$ to $< 10^{-5}$**

Table 26, Risk reduction factor, as function of SIL levels and Availability

PFDavg "weight" in SIF

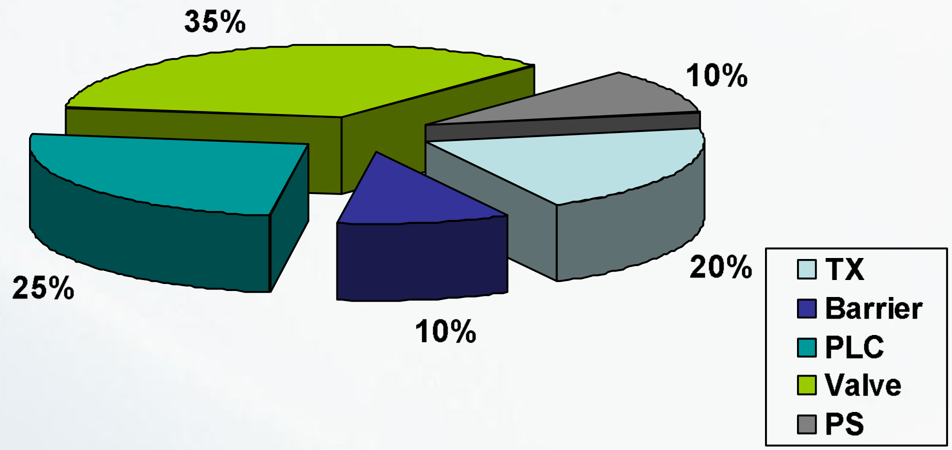
Each subsystem's PFDavg has a percentage value in relation to the total.

Component manufacturers list, in their functional safety manual, the value of PFDavg obtained by authorized certification bodies like TUV, EXIDA, FM, etc.

These bodies apply a conventional "weighing" of the PFDavg of the component in consequence of the importance that it has in the entire loop, as reported in the example:

Subsystem	PFDavg 1oo1 (%)
Transmitter	20 %
Barrier	10 %
PLC	25 %
Valve	35 %
Power Supply	10%
Total (SIF)	100 %

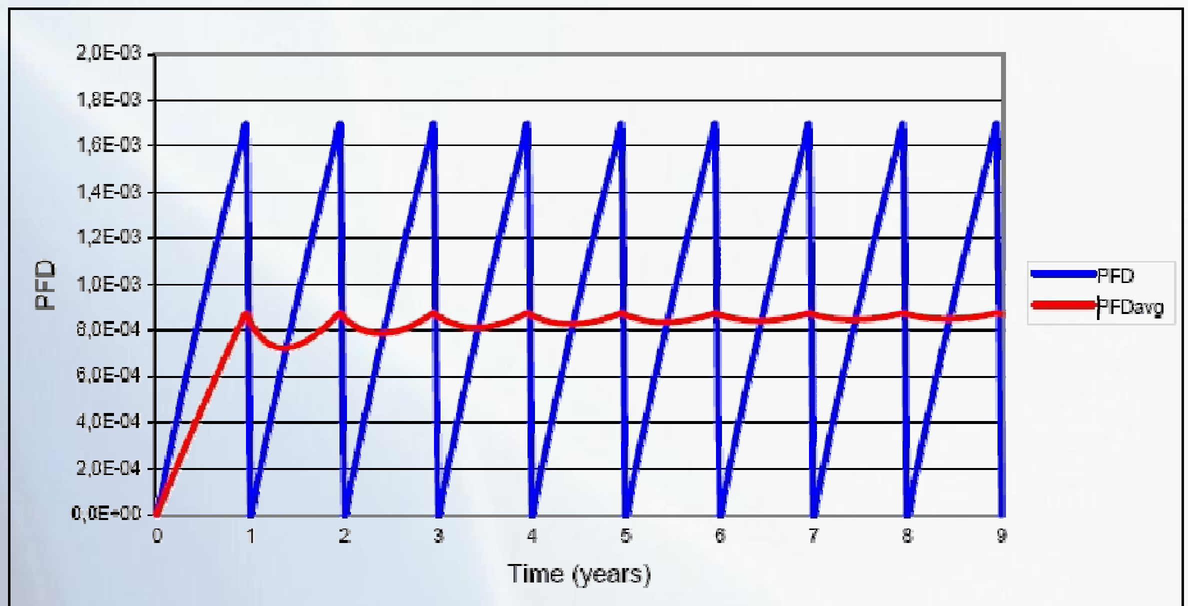
Table 5, PFDavg "weighing" for 1oo1 system architecture



PFD Versus T- proof time interval (TI)

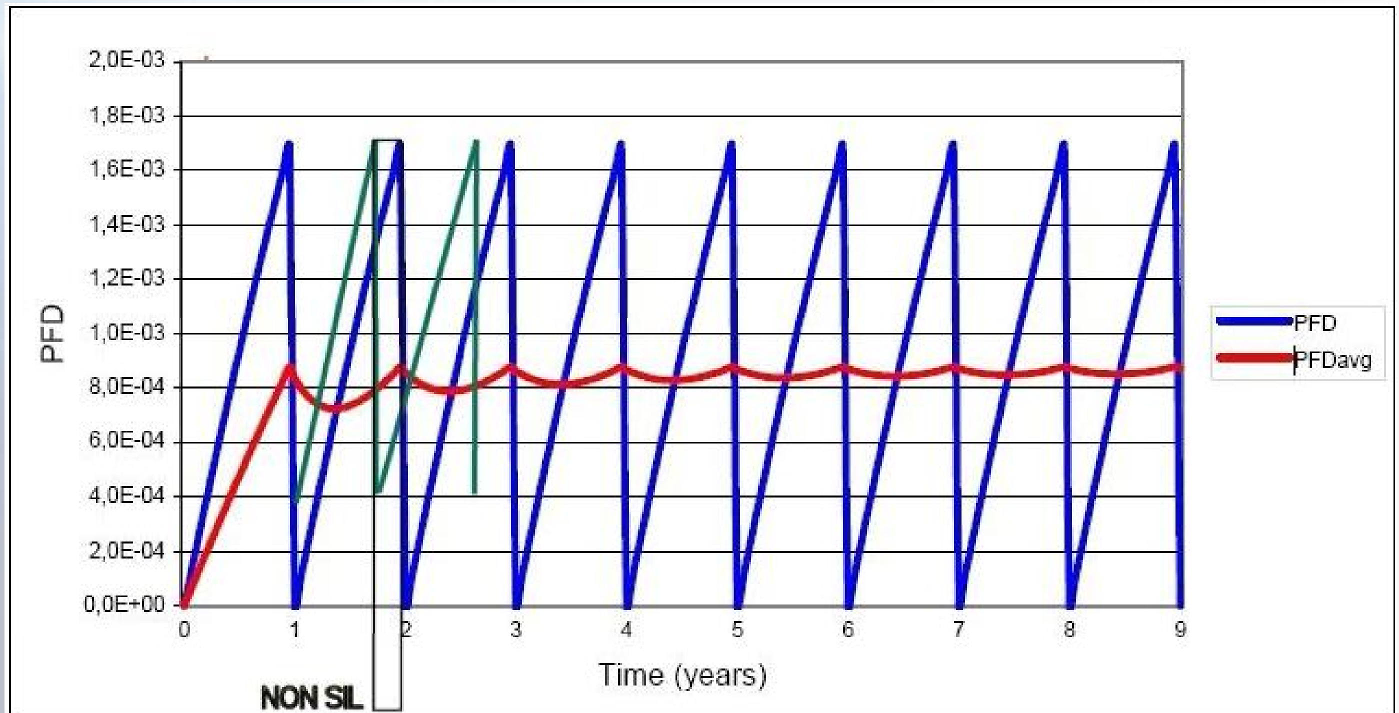
PFD degrades in time.

The probability of failure of any equipment (therefore the PFD of a SIF) increases with time.



How PFD changes in time

If the effectiveness is (99-100%) the equipment can be considered “as new”, from a probability of failure point of view, if it is lower then 100% (eg: 70-80-90%), then the SIL level could expire and not reach the required SIL level.

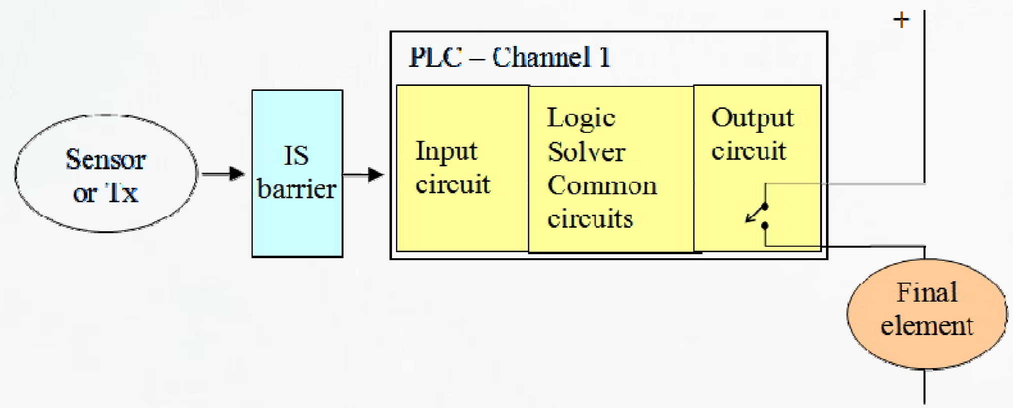


PFDavg: Equations and Examples

$$PFDavg\big|_{TI=1,SL=12} = (Et \times \frac{\lambda_{DU}}{2}) + \left[(1 - Et) \times \lambda_{DU} \times \frac{12}{2} \right]$$

Example a:

$\lambda du = 0,01$ / yr
TI = 1 yr
Et = 90% = 0,9
SL = 12 yr



At installation:

PFDavg = 0,01 / 2 = 0,005
RRF = 1 / PFDavg = 1 / 0,005 = **200 (SIL 2)**

After one year:

PFDavg = (0,9 x 0,01 / 2) + (0,1 x 0,01 x 6) = 0,0105
RRF = 1 / PFDavg = 1 / 0,0105 = **95 (SIL 1)**

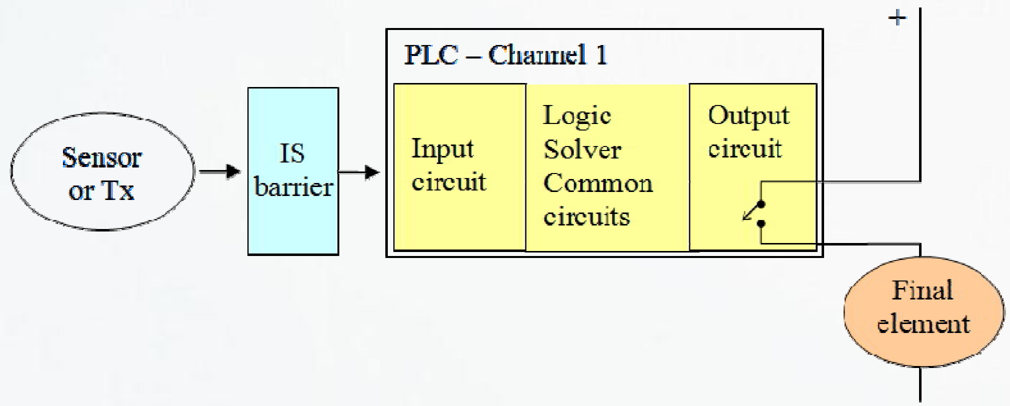
Note: **after one year (or after each periodic test) SIL 2 level has become SIL 1.**

PFDavg: Equations and Examples

$$\text{PFDavg}\Big|_{TI=1,SL=12} = (Et \times \frac{\lambda_{DU}}{2}) + \left[(1 - Et) \times \lambda_{DU} \times \frac{12}{2} \right]$$

Example b:

λdu = 0,01 / yr
TI = 1 yr
Et = 99% = 0,99
SL = 12 yr



At installation:

PFDavg = 0,01 / 2 = 0,005
RRF = 1 / PFDavg = 1 / 0,005 = **200**

After one year:

PFDavg = (0,99 x 0,01 / 2) + (0,1 x 0,01 x 6) = 0,0056
RRF = 1 / PFDavg = 1 / 0,0056 = **178**

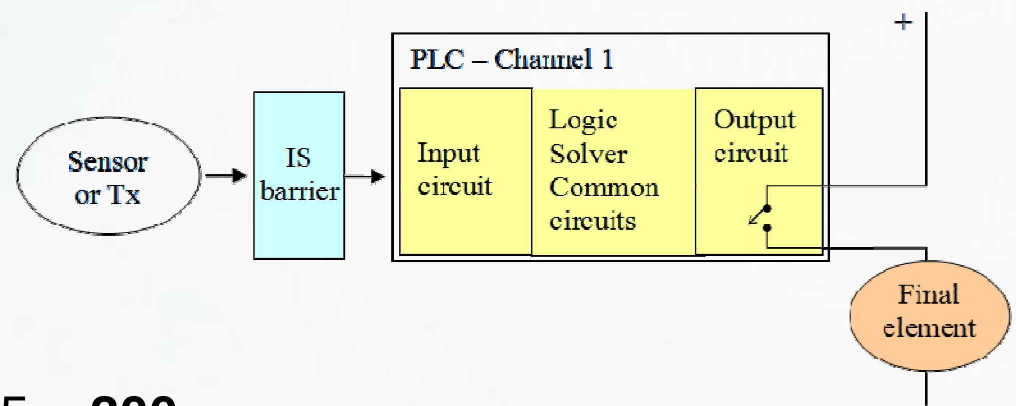
Note: **after one year (or after each periodic test) SIL 2 level is maintained.**

PFDavg: Equations and Examples

$$PFDavg\big|_{TI=1,SL=12} = (Et \times \frac{\lambda_{DU}}{2}) + \left[(1-Et) \times \lambda_{DU} \times \frac{12}{2}\right]$$

Example c:

λdu = 0,01 / yr
TI = 1 yr
Et = 90% = 0,9
SL = 5 yr



At installation:

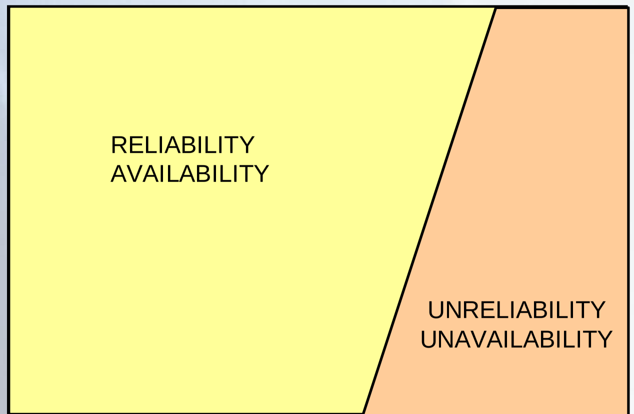
PFDavg = 0,01 / 2 = 0,005
RRF = 1 / PFDavg = 1 / 0,005 = **200**

After one year:

PFDavg = (0,9 x 0,01 / 2) + (0,1 x 0,01 x 2,5) = 0,007
RRF = 1 / PFDavg = 1 / 0,007 = **143**

Note: **Shorter Life Time improve loop PFD; partial T-proof tests every year and 100% T-proof test, or components replacement, every 5 years for SIL 2.**

Availability



Availability time (hrs)	Repair time (Hrs)	Availability (%)
1000	10	99
10000	10	99,9
100000	10	99,99
1000000	10	99,999

- SIL 2 level requires an availability of 99,9%.
- In 1 year, about 8 hours of unavailability:

1yr = 8,760 hrs; 100-99,9 = 0,1%; 0,1% of 8,760 = 8,76 hrs.

Test Duration influence on PFDavg

$$\mathrm{PFDavg} = \lambda_{\mathrm{DU}} \times \frac{\mathrm{TI}}{2} + \frac{\mathrm{TD}}{\mathrm{TI}}$$

Example d:

λdu = 0,002 / yr
TI = 1 yr
TD = 8 hrs (time interval)
PFDavg = 0,001+0,0009=0,0019
RRF = 1/ 0,0019 = **526**
(**SIL 2**)

Example e:

λdu = 0,002 / yr
TI = 1 yr
TD = 96 hrs
PFDavg = 0,001+0,01=0,011
RRF = 1/ 0,011 = **90**
(**SIL 1**)