The purpose of this SAMPLE document is to show in the public domain a typical FMDEA Study Report For a "Actuator-Positioner-Valve" (APV) arrangement, developed by:

LIUTAIO
"FUNCTIONAL SAFETY SERVICES"

For preparing this SAMPLE report, examples and public data of actuators, positioner and valves was used in combination with

LIUTAIO experience.

However, when this report is prepared for a CUSTOMER, only the authorized or provided information by CUSTOMER will be used, and the report **WILL NOT BE** part of the public domain

In practice, Valve VENDORs/Manufacturers consider as CONFIDENTIAL a document/report like this one. Information like this one **WILL NOT** be found in the public domain.

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1. Document purpose

The purpose of this SAMPLE document is to show in the public domain a typical "FMDEA Study Report" developed by **LIUTAIO** "Functional Safety Services", for an "Actuator-Positioner-Valve" (APV) arrangement, as a requirement from a Customer (in this case, typically a Valve VENDOR/Manufacturer).

For preparing this SAMPLE report, examples and public data of actuators, positioner and valves was used in combination with **LIUTAIO** experience.

However, when this report is prepared for a CUSTOMER, only the authorized or provided information by CUSTOMER will be used, and the report **WILL NOT BE** part of the public domain.

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2. Abbreviations

Refer to SAMPLE document: 0418D10SD01 Abbreviations

3. Glossary

Refer to SAMPLE document: 0418D10SD02 Glossary

4. References

4.1 Professional information and Standards

[P1] **LIUTAIO** – Functional Safety Services
0418D10SD01 Abbreviations - Sample Document
Rev.01

[P2] **LIUTAIO** – Functional Safety Services
0418D10SD02 Glossary - Sample Document
Rev.01

[P3] IEC-60812 2006 Procedure for Failure Mode and Effects Analysis (FMEA)

[P4] William M. Goble, and Harry Cheddie.
Safety Instrumented Systems Verification - Practical Probabilistic Calculations
ISA 2005.

[P5] **LIUTAIO** – Functional Safety Services
0418G25SD11 FMEDA Background - Sample Document
Rev.01

4.2 Documents provided by Customer

Not included in this SAMPLE document.

4.3 Document that WILL BE developed and delivered by LIUTAIO

[D1] **LIUTAIO** – Functional Safety Services
0418G25SD12 FMEDA study report - Sample Document (**this document**)
Rev.01

[D2] **LIUTAIO** – Functional Safety Services
0418G25SD12 FMEDA assessment - Sample Document
Rev.01

[D3] **LIUTAIO** – Functional Safety Services
0418G25SD14 Rev.01 APV Arrangement "SIL Certificate" - Sample Document
Rev.01

5. Document LIABILITY

LIUTAIO prepares FMEDA reports based on methodologies supported in International Standards. The used data is provided by Customer or from public and available databases and documental references.

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6. FMEDA study

6.1 FMEDA study objective

An Actuator-Positioner-Valve (APV) arrangement shall be used as a final element in a "Safety Instrumented Function" (SIF).

It is required to issue the arrangement "SIL Certificate" to determine if the APV arrangement satisfies SIL-3 rating in fault tolerance 0 or 1 configuration.

This document is focused in developing the FMEDA study ONLY.

The document "0418G25SD13 Rev.01 FMEDA assessment" is focused in developing the FMEDA assessment, which includes the "SIL Certificate". "SIL Certificate" shall include for each FMEDA analysis scenario:

- Failure rates (LdSD, LdSU, LdDD & LdDU),
- "Safe Failure Fraction" (SFF),
- "Proof Test Effectiveness" (Et) or "Proof Test Coverage" (PTC), and
- Satisfied "SIL rating" for fault tolerance 0 and 1 configuration.
- PFDavg value for "Proof Test Period" of 1 and 2 years (1oo1).

6.2 FMEDA execution strategy

The "FMEDA study" is a working session like HAZOP (Hazard and Operability Study).

In HAZOP session, members of the engineering disciplines involved in a process plant design, will identify plant "Hazards", failure modes and effects; and will define actions to reduce risk of identified hazards.

A "FMEDA study" is a working session conducted by a CHAIRMAN (**LIUTAIO** representative), where **LIUTAIO** and a Customer's multidisciplinary team will combine efforts to classify failure modes and effect as Dangerous/Safe failures, Detected/Undetected failures and distribution of component failure rates among failure modes.

LITUAIO HAS the expertise to perform the FMEDA study, **BUT** the Customer (Valve VENDOR/Manufacturer) involvement in the FMEDA study is required because ONLY the Customer DOES HAVE the expertise and detail know-how in the day to day design, manufacturing, installation and commissioning of industrial valves.

During the "FMEDA study" **LIUTAIO** will make emphasis in identifying "Fault detection capabilities" (Diagnostics) and "Safe Undetected Failures" of the APV arrangement, that will lead to improve this arrangement "Diagnostics" scope and SIL rating.

LIUTAIO will prepare the "FMEDA study report" to formally record all "FMDEA Study", decision notes and minute of meeting.

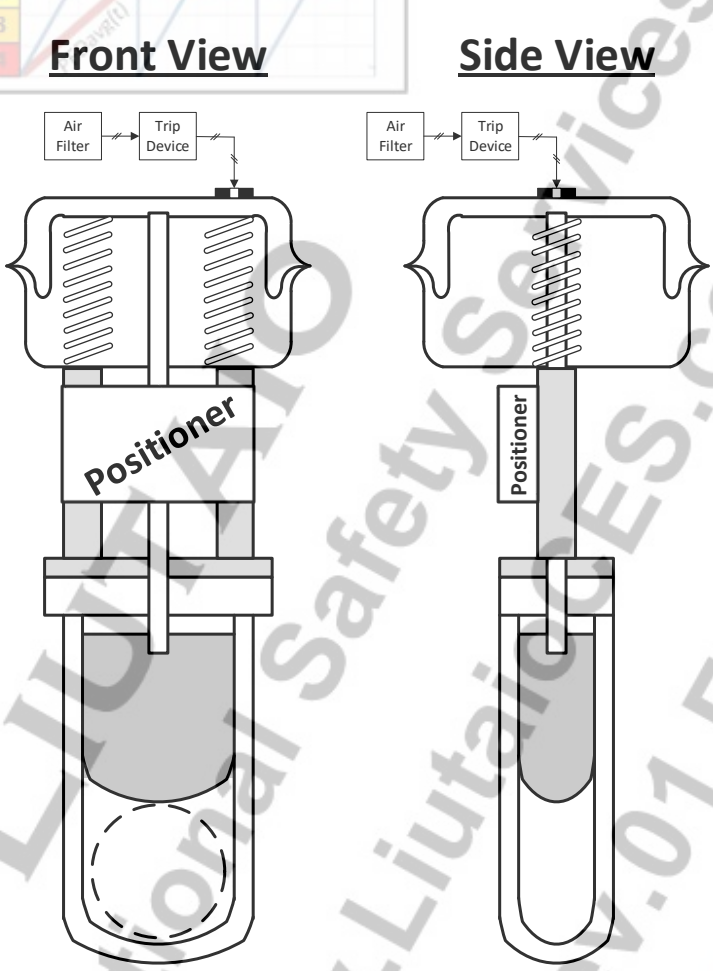
The "FMEDA study report" is the input to develop the "FMEDA assessment".

6.2.1 Failure classification that were used in this FMEDA study

Fail Safe	Failure that causes a "Target System" to move from the NORMAL to the SAFE state. Typically identified as a "Spurious Trip".
Fail Dangerous	Failure that prevents a "Target System" to fail on demand. In other words, when a HAZARD occurs, the "Target System" **CANNOT** perform its automatic protection function and it will remain in the NORMAL state.
Fail Detected	Failure in a "Target System" that can be "Detected" by an automatic diagnostic test, and this test implementation is capable to notify both a Safety/Control system and Operator. An automatic diagnostic test execution frequency **MUST BE** higher than a "Proof Test" execution frequency.
Fail UnDetected	Failure that **CANNOT** be "Detected" in a "Target System" by an automatic diagnostic test. Notification capability **DOES NOT** exist.
No Effect	Failure that has "NO Effect" in a "Target System" automatic protection function. In other words, failure that **DOES NOT** prevent a "Target System" to perform its automatic protection function and **DOES NOT** initiate "Spurious Trip".
Annunciation	Failure that has "NO Effect" in a "Target System" capability to perform its automatic protection function, BUT the "Target System" automatic diagnostic test stop to work. In other words, this failure **HAS NO** impact in safety, **BUT** "Fault Detection Capabilities" (Diagnostics) **WILL NOT** work.
Fluid Leakage	Failure that causes a "Process Fluid" leakage in a "Target System".
Air Leakage	Failure that causes an "Air" leakage in a "Target System".

6.3 Description of "Target System" under study

Figure 1 – Actuator-Positioner-Valve arrangement sketch



The "Target System" under study is an Actuator-Positioner-Valve (APV) arrangement as shown in Figure 1.

The "Air Filter" and "Trip Device" are OUT OF THE SCOPE in this study, and they shall be included as part of a SIF design and "SIL verification".

The safety valve is gate type.

The Actuator is diaphragm pneumatic type, fail to open, installed at the top of a gate safety valve.

The Positioner is installed on the actuator yoke, with a mechanical connection to the actuator stem to measure actuator/valve opening position.

Possible installed limit switches to detect Closed/Opened valve positions, and the Positioner **CANNOT** interfere the Actuator-Valve operation in any way.

The Positioner is connected to "Control/Safeguarding system" to monitor de "Valve" position, and to notify Operator when a "Dangerous Detected" failure is revealed.

The APV arrangement installation **MAY** or **MAY NOT** include logic in "Control/Safeguarding system" to execute a "Full Valve Stroke Test" (FVST).

NOTE: Since the "Positioner" is monitoring the valve position, then when the valve moves **WITHOUT** command, the "Positioner" (or installed FVST) can notify Safety/Control System and Operator.

In the APV arrangement:

- A dangerous failure in the "Actuator" will make the valve to fail on demand.
- A dangerous failure in the "Valve" will make the actuator to fail on demand.
- **BUT**, any kind of failure in the "Positioner" may lead to lose of the APV arrangement "Fault Detection Capabilities" only.

6.3.1 "Target System" structure

In the "Target System", a Dangerous failure in the "Actuator" will make the "Valve" to fail on demand, and vice versa.

Figure 2 shows the "Target System" structure for FMEDA study in the form of a very simple "Reliability Block Diagram" (RBD). Notice that the "Positioner" **DOES NOT** appear in the RBD, because any kind of failure in the "Positioner" **WILL NOT** make the APV arrangement to fail on demand. The "Positioner" installation ONLY monitors the valve position, and it **HAS NO** effect in the APV operation.

It is a fact that a mechanical device **DOES NOT** include "Fault Detection Capabilities" (Diagnostics), unless it is combined with an electronic device that can monitor the mechanical device performance.

Some valves "SIL Certificates" declare "Safe Detected" and/or "Dangerous Detected" failure rate with other than ZERO(0.0) values, but they **DO NOT** indicate which electronic device is performing "Diagnostics" and which fails are monitored. It is IMPORTANT to indicate with electronic device will perform the mechanical device "Diagnostics".

NOTE: in some "Partial Valve Stroke Test" (PVST) applications the "Positioner" is capable to regulate the "Valve" position. ONLY in such cases, the "Positioner shall be included in the RBD.

Figure 2 – APV arrangement "Reliability Block Diagram"

Since any kind of failure in the "Positioner" **WILL NOT** make the APV arrangement to fail on demand, it **IS NOT** required to develop the FMEDA tables for this device.

6.4 FMEDA analysis conditions and scenarios

The way the APV arrangement fails in an operation/environment condition CAN CHANGE WHEN THE APV ARRANGEMENT is working in a different operation/environment condition.

Table 1 and Table 2 describe the operation/environment conditions which define the scope of work in this FMEDA study.

From Table 1 and Table 2, the analysis scenarios to consider in this study are:

1) "Fail Open" APV arrangement (Open to Trip), with FVST.
2) "Fail Open" APV arrangement (Open to Trip), NO FVST.
3) "Fail Open" APV arrangement (Close to Trip), with FVST.
4) "Fail Open" APV arrangement (Close to Trip), NO FVST.

Table 1 – Operational/Working conditions to consider for APV arrangement FMEDA study

#	Operation/Working conditions	Included in study	Excluded from study	Remarks	#
1	Effect of Abrasive fluid passing through valve (erosion).		Excluded		1
2	Effect of Corrosive fluid passing through valve.		Excluded		2
3	General Liquid fluid passing through valve.	YES			3
4	Orientation installation of Fluid passing through valve.	**Not Applicable**		flow through valve plug top to bottom, or vice versa.	4
5	General Gas fluid passing through valve.		Excluded		5
6	Single phase or steam flow through valve		Excluded		6
7	Flow is flashing (vaporization) through valve		Excluded		7
8	Multi-Phase phase flow through valve		Excluded		8
9	Pressure	General Operation	High Pressure service	Above 6.4 MPa (64 Bar), or above ANSI CLASS 900	9
10			Low Pressure service	Below atmospheric pressure	10
11	Temperature.	General Operation 0-400°C (32-752°F)	High Temperature service	Above 400°C (752°F)	11
12			Cryogenic service	Below -150°C (-238°F)	12
13	Daily temperature excursion (peak to peak)	10°C (50°F)			13
14	Use of Hydraulic fluid to move valve actuator.		Excluded	Hydraulic package **IS NOT** included.	14
15	Use of Pneumatic fluid to move valve actuator.	YES		Instrument Air system **IS NOT** included.	15
16	Hydraulic, Pneumatic, or any other trip device to move the Actuator-Valve from NORMAL to SAFE state (Opened or Closed).		Excluded		16
17	Use of Electrical actuator to move valve.		Excluded		17
18	Use of handwheel to move the valve.		Excluded		18
19	Fail Close valve (Close to trip)		Excluded		19
20	Fail Open valve (Open to trip)	YES			20
21	Fail Close valve (Open to trip)		Excluded		21
22	Fail Open valve (Close to trip)	YES			22
23	Fail lock-in-last position valve		Excluded	Typically, double acting actuator	23
24	Tight-Shutoff valve		Excluded		24
25	FVST – Full Valve Stroke Test	YES and NO			25
26	PVST – Partial Valve Stroke Test		Excluded		26

Table 2 - Environment and site installation conditions to consider for APV arrangement FMEDA study

#	Environment/Site conditions	Included in study	Excluded from study	Remarks	#
1	Surrounding Environment Temperature	0-40°C (32-104°F)			1
2	Surrounding Pressure	Atmospheric			2
3	Typical field industrial installation at grade, or at Deck elevation.	YES			3
4	APV arrangement is installed in Vertical or horizontal position	YES			4
5	Dusty environment		Excluded		5
6	Exposed to Elements / Weather condition changes	Moderate (Light rain)		Heavy rain, Thunder (Lightning), Typhon, Tornado or Hurricane **IS NOT** included.	6
7	Explosive/Inflammable area installation location	YES			7
8	Outdoors installation location	YES			8
9	Indoors @ Factory building		Excluded		9
10	Sheltered installation location		Excluded		10
11	Underwater installation location		Excluded		11
12	Underground installation location		Excluded		12
13	Humidity. Non-Condensing environment	YES		5-95% relative humidity	13
14	Humidity. Condensing environment		Excluded		14
15	Vibration at installed location	No-Vibrations			15
16	Solar radiation.	YES		Arrangement under shade in worst case.	16
17	Electromagnetic interference		Excluded		17

6.5 FMEDA study results

As described in above section 6.3.1, in this SAMPLE document the "FMEDA study" shall be performed ONLY for the "Actuator" and "Valve" in the APV arrangement.

For both "Pneumatic Actuator" and "Gate Valve" data **IS NOT** available in the public domain.

NOTE: normally "Actuators" and "Valves" FMEDA data for a "FMEDA study" **IS NOT** available in the public domain. This information is considered CONFIDENTIAL by valve's VENDOR/Manufacturer.

For this SAMPLE document:

For "Gate Valve": A public "SIL Certificate" from a "Gate Valve" VENDOR shall be used to develop the FMEDA assessment. See reference [D2]. No FMEDA tables will be developed.

See: <PUBLIC GATE VALVE SIL CERTIFICATE> (Type A device)

For "Pneumatic Actuator": Data from reference [P5] is used as an example to develop "Actuator" FMEDA tables. **LIUTAIO** experience was applied to analyse the data in order to produce a realistic result applicable for the "Target System" in this FMEDA study report.

The FMEDA study results are recorded in the "Actuator" FMEDA tables that are shown in the "APPENDIX B", "APPENDIX C" and "APPENDIX D" for the analysis scenarios No.1, No.2 and No.3/4, respectively. Refer to above section 6.3.1 for scenarios and conditions description.

"APPENDIX A" shows the FMEDA table columns description.

NOTE: Notice that as result of FMEDA study, the Failure effect between tables in "APPENDIX B/C" and "APPENDIX D" **ARE NOT** the same ones for the same Failure modes. This is an evidence that the APV arrangement behavior/performance **IS NOT** the same one in different scenarios.

NOTE: "Proof Test Effectiveness" (Et), or "Proof Test Coverage" (PTC), will be calculated with data from "Actuator" ONLY, because the FMEDA data from the "Valve" **IS NOT** available.

It is assumed that during FMEDA study session Customer presented "In House" failure data records. Base on this fact, it can be considered that the "Actuator" is a device "**Type A**".

Since both "Actuator" and "Valve" are "**Type A**" device and they perform in series (See RBD in section 6.3.1), then by applying "Route 1H" (IEC-61508-2 2010, section 7.4.4.2) the APV arrangement is "**Type A**" as well.

The FMEDA study report shall also include notes and a minute of meeting from the FMEDA study session, but that information is no included in this SAMPLE document.

APPENDIX A - "Actuator" FMEDA table columns description

Column A: Comp ID

Component identification number.

Column B: Component description

Column C: Qty

Amount of component in use that are performing the same function in the "Actuator", and they make redundancy each other.

Quantity of components in parallel that are working in 1ooN REDUNDANCY.

=1 NO redundancy. ONLY one(1) component is used.

>1 two(2) or more components are used with 1ooN REDUNDANCY.

Column D: Failure Mode description

Column E: Effect description

Column F: Component Failure Rate [1 / h]

Component identified failure rate in [1/h]

Column G: Failure Mode Ratio

Portion of component failure rate that is allocated for the indicated failure mode in [%].

In other words, chance that the indicated failure mode-effect occurs, among other effects for the same failure mode.

Total of FMR for one component MUST BE equal to 100%.

Column H: Failure Type (D, S, #)

Type of failure associated to the Failure Mode:

=D Dangerous failure

=S Safe failure

=# Residual failure

A Residual failure **DOES NOT** have effect in the PFDavg and PFHavg.

A Residual failure can be classified as: Residual, No Effect, Annunciation failure, Leakage failure, etc.

Column I: Diagnostics – Detected by Positioner

=Yes Failure is detected by Positioner when it occurs.

=EMPTHY Positioner CANNOT detect failure.

Column J: Diagnostics – Detectable Ratio

Portion of component failure rate where a "Diagnostic" applies to identify (to detect) the indicated failure mode-effect in the range 0-100%.

=0% it **IS NOT** possible to detect when the indicated failure mode-effect occurs.

>0% and < 100% a "Diagnostic" has partial capability to identify (to detect) when the indicated mode-failure effect occurs.

= 100% a "Diagnostic" is capable to identify (to detect) when the indicated failure effect occurs.

Column K: Diagnostic – Description

Column L: Can "Proof Test" reveal DU

This column indicates when "Proof Test" CANNOT reveal the indicated "Dangerous UnDetected" (DU) failure; or just a portion of it because the failure can be revealed only some times when the "Proof Test" is applied.

=BLACK	background color means: Not Applicable.
=EMPTY	Yes, "Proof Test" can.
=NO	NO, "Proof Test" **CANNOT** reveal the indicated "Dangerous UnDetected" (DU) failure.
=0% to 100%	"Proof Test" can reveal the "Dangerous Detected" (DU) failures ONLY the indicated proportion of times when the "Proof Test" is applied".

Column M: SLf [m]

Service Life, or Replace period, or Mission time in [months].

SLf >0.0

Column N: # - Other Failure Classification

APPENDIX B - "Actuator" FMEDA table for the analysis scenario No.1: "Fail Open" APV arrangement (Open to Trip), with FVST

Project	**SIL Certification**
Target System	**Actuator-Positioner-Valve arrangement**
Analysis Scenario	**No.1 - "Fail Open" APV arrangement (Open to Trip), with FVST.**

A	B	C	D	E	F	G	H	I	J	K	L	M	N	
								Diagnostics						
	Comp ID	Component description	Qty	Failure Mode description	Effect description	Comp Failure Rate[1/h]	Failure Mode Ratio	Failure Type D,S,#	Detected by Positioner	Detectable Ratio	Description	Can "Proof Test" reveal DU	SLf [m]	# - Other Failure classificaton	Notes	
1	1	Housing	1	Fracture	Torque transmission failure	5.00E-09	95.0%	D					12			1
2			1	Deflection	No effect	5.00E-09	5.0%	#					12	No Effect		2
3	2	Housing cover	1	Fracture	Valve will not move	5.00E-09	95.0%	D					12			3
4			1	Deflection	No Effect	5.00E-09	5.0%	#					12	No Effect		4
5	3	Guide block assembly	1	Fracture - piston side power SW	Spring force will cause shutdown	3.00E-08	31.7%	S					12			5
6			1	Fracture - spring side power SW	Valve will not move	3.00E-08	31.7%	D		100.0%			12			6
7			1	Fracture - middle	Valve will not move	3.00E-08	31.7%	D		100.0%			12			7
8			1	Deflection	No Effect	3.00E-08	5.0%	#					12	No Effect		8
9	4	Extension rod assembly	1	Fracture	Spring force will cause shutdown	5.00E-08	95.0%	S					12			9
10			1	Deflection	No Effect	5.00E-08	5.0%	#					12	No Effect		10
11	5	Extension retainer nut assembly	1	Loss of Thread	Spring force will cause shutdown	5.00E-08	20.0%	S					12			11
12			1	Loosen	Spring force will cause shutdown	5.00E-08	80.0%	S					12			12
13	6	Yoke	1	Fracture	Valve will not move	1.00E-07	75.0%	D	Yes	80.0%		80.0%	12	Annunciation	Note 1	13
14			1	Deflection	Valve will be fully seated	1.00E-07	20.0%	D	Yes	80.0%		80.0%	12	Annunciation	Note 1	14
15			1	Wear	Valve will be fully seated	1.00E-07	5.0%	D		0.0%			12			15
16	7	Yoke Pin	1	Fracture	Valve will not move	6.00E-08	95.0%	D		0.0%			12			16
17			1	Deflection	Valve not fully seated	6.00E-08	5.0%	D	Yes	100.0%			12	Annunciation	Note 1	17
18	8	Guide bar bearing	1	Excessive friction	No Effect	3.00E-08	40.0%	#					12	No Effect		18
19			1	Excessive play	Valve will not move	3.00E-08	10.0%	#					12	No Effect		19
20			1	Seized	Valve will not move	3.00E-08	50.0%	D					12			20
21	9	Yoke Pin bearing	1	Excessive friction	Process Safety Time may not be satisfied	3.00E-08	40.0%	D				50.0%	12			21
22			1	Excessive play	No Effect	3.00E-08	10.0%	#					12	No Effect		22
23			1	Seized	Valve will not move	3.00E-08	50.0%	D					12			23
24	10	Yoke/Guide block bushing	2	Tear	No Effect	3.00E-08	100.0%	#					12	No Effect		24
25	11	Yoke bearing	2	Excessive friction	Process Safety Time may not be satisfied	3.00E-08	40.0%	D				50.0%	12			25
26			2	Excessive play	No Effect	3.00E-08	10.0%	#					12	No Effect		26
27			2	Seized	Valve will not move	3.00E-08	50.0%	D					12			27
28	12	O-ring seal	2	Leak	N/A		99.0%	#					12	No Effect		28
29			2	Complete failure	N/A		1.0%	#					12	No Effect		29
30	13	Rod wiper	1	N/A	N/A		100.0%	#					12	No Effect		30
31	14	O-ring seal	2	Leak	N/A		99.0%	#					12	No Effect		31
32			2	Complete failure	N/A		1.0%	#					12	No Effect		32
33	15	Inner end cap	1	Fracture	Air leak	2.50E-08	95.0%	S	Yes	50.0%			12	Annunciation	Note 1	33
34			1	Deflection	Air leak	2.50E-08	5.0%	S		0.0%			12			34
35	16	Tie bar	2	Fracture	Valve will not move	2.50E-08	5.0%	D					12			35
36			2	Fracture	Release of pressure	2.50E-08	90.0%	S					12			36
37			2	Deflection	Valve will not move	2.50E-08	1.0%	D					12			37
38			2	Deflection	Release of pressure	2.50E-08	4.0%	S					12			38
39	17	Piston	1	Fracture	Spring force will cause shutdown	2.50E-08	95.0%	S		0.0%			12			39
40			1	Deflection	Valve will not fully seated	2.50E-08	5.0%	D	Yes	50.0%		50.0%	12	Annunciation	Note 1	40

NOTE 1 The Failure Mode-Effect becomes an "Annunciation" failure when the "Positioner" fails.

APPENDIX C - "Actuator" FMEDA table for the analysis scenario No.2: "Fail Open" APV arrangement (Open to Trip), NO FVST

Project	**SIL Certification**
Target System	**Actuator-Positioner-Valve arrangement**
Analysis Scenario	**No.2 - "Fail Open" APV arrangement (Open to Trip), NO FVST.**

A	B	C	D	E	F	G	H	I	J	K	L	M	N	
								Diagnostics						
	Comp ID	Component description	Qty	Failure Mode description	Effect description	Comp Failure Rate[1/h]	Failure Mode Ratio	Failure Type D,S,#	Detected by Positioner	Detectable Ratio	Description	Can "Proof Test" reveal DU	SLf [m]	# - Other Failure classificaton	Notes	
1	1	Housing	1	Fracture	Torque transmission failure	5.00E-09	95.0%	D					12			1
2			1	Deflection	No effect	5.00E-09	5.0%	#					12	No Effect		2
3	2	Housing cover	1	Fracture	Valve will not move	5.00E-09	95.0%	D					12			3
4			1	Deflection	No Effect	5.00E-09	5.0%	#					12	No Effect		4
5	3	Guide block assembly	1	Fracture - piston side power SW	Spring force will cause shutdown	3.00E-08	31.7%	S					12			5
6			1	Fracture - spring side power SW	Valve will not move	3.00E-08	31.7%	D					12			6
7			1	Fracture - middle	Valve will not move	3.00E-08	31.7%	D					12			7
8			1	Deflection	No Effect	3.00E-08	5.0%	#					12	No Effect		8
9	4	Extension rod assembly	1	Fracture	Spring force will cause shutdown	5.00E-08	95.0%	S					12			9
10			1	Deflection	No Effect	5.00E-08	5.0%	#					12	No Effect		10
11	5	Extension retainer nut assembly	1	Loss of Thread	Spring force will cause shutdown	5.00E-08	20.0%	S					12			11
12			1	Loosen	Spring force will cause shutdown	5.00E-08	80.0%	S					12			12
13	6	Yoke	1	Fracture	Valve will not move	1.00E-07	75.0%	D				80.0%	12			13
14			1	Deflection	Valve will be fully seated	1.00E-07	20.0%	D				80.0%	12			14
15			1	Wear	Valve will be fully seated	1.00E-07	5.0%	D					12			15
16	7	Yoke Pin	1	Fracture	Valve will not move	6.00E-08	95.0%	D					12			16
17			1	Deflection	Valve not fully seated	6.00E-08	5.0%	D					12			17
18	8	Guide bar bearing	1	Excessive friction	No Effect	3.00E-08	40.0%	#					12	No Effect		18
19			1	Excessive play	Valve will not move	3.00E-08	10.0%	#					12	No Effect		19
20			1	Seized	Valve will not move	3.00E-08	50.0%	D					12			20
21	9	Yoke Pin bearing	1	Excessive friction	Process Safety Time may not be satisfied	3.00E-08	40.0%	D				50.0%	12			21
22			1	Excessive play	No Effect	3.00E-08	10.0%	#					12	No Effect		22
23			1	Seized	Valve will not move	3.00E-08	50.0%	D					12			23
24	10	Yoke/Guide block bushing	2	Tear	No Effect	3.00E-08	100.0%	#					12	No Effect		24
25	11	Yoke bearing	2	Excessive friction	Process Safety Time may not be satisfied	3.00E-08	40.0%	D				50.0%	12			25
26			2	Excessive play	No Effect	3.00E-08	10.0%	#					12	No Effect		26
27			2	Seized	Valve will not move	3.00E-08	50.0%	D					12			27
28	12	O-ring seal	2	Leak	N/A		99.0%	#					12	No Effect		28
29			2	Complete failure	N/A		1.0%	#					12	No Effect		29
30	13	Rod wiper	1	N/A	N/A		100.0%	#					12	No Effect		30
31	14	O-ring seal	2	Leak	N/A		99.0%	#					12	No Effect		31
32			2	Complete failure	N/A		1.0%	#					12	No Effect		32
33	15	Inner end cap	1	Fracture	Air leak	2.50E-08	95.0%	S					12			33
34			1	Deflection	Air leak	2.50E-08	5.0%	S					12			34
35	16	Tie bar	2	Fracture	Valve will not move	2.50E-08	5.0%	D					12			35
36			2	Fracture	Release of pressure	2.50E-08	90.0%	S					12			36
37			2	Deflection	Valve will not move	2.50E-08	1.0%	D					12			37
38			2	Deflection	Release of pressure	2.50E-08	4.0%	S					12			38
39	17	Piston	1	Fracture	Spring force will cause shutdown	2.50E-08	95.0%	S					12			39
40			1	Deflection	Valve will not fully seated	2.50E-08	5.0%	D				50.0%	12			40

APPENDIX D - "Actuator" FMEDA table for the analysis scenario No.3 & 4: "Fail Open" APV arrangement (Close to Trip), with and WITHOUT FVST, respectively.

Project	**SIL Certification**
Target System	**Actuator-Positioner-Valve arrangement**
Analysis Scenario	**No.3 & 4 - "Fail Open" APV arrangement Close to Trip), with and WITHOUT FVST, respectively**

A	B	C	D	E	F	G	H	I	J	K	L	M	N	
								Diagnostics						
	Comp ID	Component description	Qty	Failure Mode description	Effect description	Comp Failure Rate[1/h]	Failure Mode Ratio	Failure Type D,S,#	Detected by Positioner	Detectable Ratio	Description	Can "Proof Test" reveal DU	SLf [m]	# - Other Failure classificaton	Notes	
1	1	Housing	1	Fracture	Torque transmission failure	5.00E-09	95.0%	D					12			1
2			1	Deflection	No effect	5.00E-09	5.0%	#					12	No Effect		2
3	2	Housing cover	1	Fracture	Valve will not move	5.00E-09	95.0%	D					12			3
4			1	Deflection	No Effect	5.00E-09	5.0%	#					12	No Effect		4
5	3	Guide block assembly	1	Fracture - piston side power SW	Valve will not move	3.00E-08	31.7%	D					12			5
6			1	Fracture - spring side power SW	Valve will not move	3.00E-08	31.7%	D					12			6
7			1	Fracture - middle	Valve will not move	3.00E-08	31.7%	D					12			7
8			1	Deflection	No Effect	3.00E-08	5.0%	#					12	No Effect		8
9	4	Extension rod assembly	1	Fracture	Valve will not move	5.00E-08	95.0%	D					12			9
10			1	Deflection	No Effect	5.00E-08	5.0%	#					12	No Effect		10
11	5	Extension retainer nut assembly	1	Loss of Thread	Valve will not move	5.00E-08	20.0%	D					12			11
12			1	Loosen	Valve will not move	5.00E-08	80.0%	D					12			12
13	6	Yoke	1	Fracture	Valve will not move	1.00E-07	75.0%	D				80.0%	12			13
14			1	Deflection	Valve will be fully seated	1.00E-07	20.0%	D				80.0%	12			14
15			1	Wear	Valve will be fully seated	1.00E-07	5.0%	D					12			15
16	7	Yoke Pin	1	Fracture	Valve will not move	6.00E-08	95.0%	D					12			16
17			1	Deflection	Valve not fully seated	6.00E-08	5.0%	D					12			17
18	8	Guide bar bearing	1	Excessive friction	No Effect	3.00E-08	40.0%	#					12	No Effect		18
19			1	Excessive play	Valve will not move	3.00E-08	10.0%	#					12	No Effect		19
20			1	Seized	Valve will not move	3.00E-08	50.0%	D					12			20
21	9	Yoke Pin bearing	1	Excessive friction	Process Safety Time may not be satisfied	3.00E-08	40.0%	D				50.0%	12			21
22			1	Excessive play	No Effect	3.00E-08	10.0%	#					12	No Effect		22
23			1	Seized	Valve will not move	3.00E-08	50.0%	D					12			23
24	10	Yoke/Guide block bushing	2	Tear	No Effect	3.00E-08	100.0%	#					12	No Effect		24
25	11	Yoke bearing	2	Excessive friction	Process Safety Time may not be satisfied	3.00E-08	40.0%	D				50.0%	12			25
26			2	Excessive play	No Effect	3.00E-08	10.0%	#					12	No Effect		26
27			2	Seized	Valve will not move	3.00E-08	50.0%	D					12			27
28	12	O-ring seal	2	Leak	N/A		99.0%	#					12	No Effect		28
29			2	Complete failure	N/A		1.0%	#					12	No Effect		29
30	13	Rod wiper	1	N/A	N/A		100.0%	#					12	No Effect		30
31	14	O-ring seal	2	Leak	N/A		99.0%	#					12	No Effect		31
32			2	Complete failure	N/A		1.0%	#					12	No Effect		32
33	15	Inner end cap	1	Fracture	Air leak	2.50E-08	95.0%	S					12			33
34			1	Deflection	Air leak	2.50E-08	5.0%	S					12			34
35	16	Tie bar	2	Fracture	Valve will not move	2.50E-08	5.0%	D					12			35
36			2	Fracture	Release of pressure	2.50E-08	90.0%	S					12			36
37			2	Deflection	Valve will not move	2.50E-08	1.0%	D					12			37
38			2	Deflection	Release of pressure	2.50E-08	4.0%	S					12			38
39	17	Piston	1	Fracture	Valve will not move	2.50E-08	95.0%	S					12			39
40			1	Deflection	Valve will not fully seated	2.50E-08	5.0%	D				50.0%	12			40