

APPENDIX A**Failure Modes Identified via FMEA RPN Assignment per Operational Unit**

Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN	Unit ID
Unsecured cylinder during transport	9	4	6	216	1,2,4-6,10,12-13,15,16-18,20-23,26,29,31-34,36,38,40,43-44,47,50
	9	5	4	180	7-9,14,25,27-28,30,39,41-42,45,48-49
	9	3	6	162	3,37
	9	4	4	144	11,19,24,35,46
Lack of safety signage	6	6	5	180	1-3,9-16,22-24,26,29-31,36,40-41,47-49
	7	5	4	140	32,37-39,42,44
	7	4	4	112	4,18-19,34
	7	3	5	105	5-6,17,20-21,25,27-28,33,50
	7	3	4	84	8,35,43,45-46
	7	2	5	70	7
Absence or misuse of PPE	5	5	8	200	1-3,5,7,9,11-17,19-20,22-23,25-26,28,31-33,35-40,43-48,50
	6	4	4	96	18,21,42,49
	6	3	4	72	4,6,8,10,24,27,29-30,34,41
Missed leak detection	8	4	5	160	1,4,6-10,12-18,22,24,26-27,30-31
	8	3	4	96	23,25,32,34-37,40-41,44-47,49
	8	3	3	72	11,20-21,29,33,42,43,48
	8	2	4	64	2-3,5,19,28,38-39,50

APPENDIX B**Performance Indicators per operational unit (KPI)**

Unit ID	Safety Protocol Compliance (%)	Training Coverage (%)	Cylinder Inspection Rate (%)	Signage Availability (%)	Composite KPI Score (%)	Incident Rate (per 10k ops)
U01	74,3	76,7	70,7	65,2	71,725	3,45
U02	71,7	74,3	71,1	69,3	71,6	3,58
U03	74,9	73,2	66	69,7	70,95	3,89
U04	78,4	77,7	70,6	67,7	73,6	3,87
U05	71,4	79,2	70,3	70,4	72,825	2,41
U06	71,4	78,9	65,1	72,8	72,05	2,68
U07	78,6	72,7	78,7	79	77,25	3,55

U08	75,4	74,5	71,8	71,8	73,375	3,55
U09	70,4	76,8	71,8	72,2	72,8	3,55
U10	74,5	79	72,7	70,8	74,25	3,58
U11	70,4	73,9	64,2	63	67,875	3,58
U12	70,4	75	73,3	71	72,425	3,92
U13	73,3	71,7	75,2	71,4	72,9	3,81
U14	74	71,4	65,3	70	70,175	3,63
U15	65,4	78,4	74,2	62,3	70,075	3,05
U16	70,1	80,3	71,5	72,4	73,575	3,7
U17	68,2	75,3	73,5	71	72	2,78
U18	73,6	79,1	78,9	66,2	74,45	3,1
U19	68,2	76,9	68,2	75,9	72,3	2,95
U20	66,3	73,3	71,8	74,3	71,425	3,29
U21	78,2	76,9	71,3	74,4	75,2	4,63
U22	71,4	81	65,3	67,3	71,25	2,12
U23	72,6	75,5	69	77	73,525	3,65
U24	73	81	71,1	65,2	72,575	2,27
U25	70,1	66,4	70,2	73,6	70,075	2,96
U26	72,7	78,5	73,5	70	73,675	3,89
U27	73,1	75,9	69,5	66,9	71,35	3,28
U28	73,8	74,6	76,7	68,7	73,45	2,59
U29	69,9	75,9	68,1	71,5	71,35	2,81
U30	71,1	68,6	83	69	72,925	3,65
U31	73	74,8	72,5	64,6	71,225	2,8
U32	79,4	76,8	65,1	70	72,825	3,37
U33	72,2	80,8	72,4	66,6	73	3,27
U34	68,1	73,8	71,8	73,1	71,7	2,85
U35	75,4	72,8	68,3	67,2	70,925	4,53
U36	67,4	73,8	73	70	71,05	3,62
U37	73,1	78,8	71,8	67,8	72,875	2,02
U38	73,1	76,8	76,7	69,7	74,075	3,35
U39	73	73,7	71,8	70	72,125	2,84
U40	73,1	77,4	71,8	65,9	72,05	3,5
U41	75,3	75,9	67,2	66,3	71,175	2,76
U42	73	79	73,7	63,4	72,275	3,17
U43	71,6	70,5	70,5	64,3	69,225	3,54
U44	71,1	74,5	63,2	71,9	70,175	3,76
U45	66,4	74,2	70,3	62,5	68,35	2,52
U46	69,4	70,5	71,3	70	70,3	3,04
U47	70,5	76,6	71,3	65,5	70,975	2,96
U48	76,5	76,5	70,2	65,6	72,2	2,85
U49	73,7	75,6	76,1	73,3	74,675	3,65
U50	73,1	74,8	63,2	72,3	70,85	3,48

APPENDIX C

Technical Field Inspection Checklist for LPG Cylinder Distribution Facilities

Applicable Standards:

- NFPA 58 – Liquefied Petroleum Gas Code
- ISO 45001:2018 – Occupational Health and Safety Management Systems
- ISO 31000:2018 and ISO/IEC 31010:2019: Guidelines and tools for risk assessment methodologies
- ISO 9001:2015: Quality management systems-Requirements

Purpose:

To evaluate regulatory compliance, operational safety, and structural adequacy in LPG cylinder storage and handling facilities through standardized technical criteria aligned with international codes.

Section 1: Storage Area Conditions

Item	Technical Evaluation Criterion	Compliant (✓/X)
1.1	Segregation of full and empty cylinders with physical barriers	
1.2	Cylinders stored upright and properly secured against tipping	
1.3	Visible signage indicating “FLAMMABLE GAS” and “NO SMOKING”	
1.4	Naturally ventilated area free of obstructions or enclosed structures	
1.5	ABC-class fire extinguishers accessible and maintained in working condition	
1.6	Functional lighting without exposed electrical wiring	
1.7	Periodic leak testing of valves using soap solution (per NFPA 58 Section 6.11.4)	

Section 2: Handling and Internal Transport Procedures

Item	Technical Evaluation Criterion	Compliant (✓/X)
2.1	Mandatory use of Personal Protective Equipment (PPE): gloves, safety shoes, eye protection	
2.2	Clearly demarcated internal routes for cylinder handling and vehicular movement	
2.3	Use of trolleys or mechanical platforms for manual cylinder transport	
2.4	No dragging or rolling of cylinders; adherence to proper lifting techniques	
2.5	Staff trained in emergency response and first aid for LPG-related incidents	

Section 3: Documentation and Regulatory Compliance

Item	Technical Evaluation Criterion	Compliant (✓/X)
3.1	Updated operational manual available on-site	
3.2	Records of personnel safety training in the last 12 months	
3.3	Internal safety audit logs and maintenance checklists maintained	
3.4	Incident reporting system with evidence of corrective actions implemented	
3.5	Certification or inspection record issued by competent regulatory authority	

APPENDIX D

Structured Interview Guide for Operational Risk Identification

Objective:

To capture qualitative insights on procedural deviations, unsafe practices, and perceived regulatory gaps from on-site personnel involved in LPG cylinder handling, transport, and storage.

Target Respondents:

- Operations Managers
- Safety Supervisors
- Technical Staff (handlers, drivers, depot operators)

Interview Structure and Content Blocks

Block 1 – Cylinder Handling and Operational Practices

- Could you describe the procedure followed when receiving LPG cylinders into the facility?
- What methods are used to unload cylinders from transport vehicles?
- How frequently are cylinder valves visually inspected or tested for leaks?
- Are manual handling tools (e.g., trolleys, racks) consistently available and used?

Block 2 – Personal Safety and Use of Protective Equipment

- What types of personal protective equipment (PPE) are provided to you?
- How often do you receive training on safe LPG handling procedures?
- What steps are you instructed to follow in case of a suspected gas leak?
- Have you participated in any emergency drills or fire response simulations?

Block 3 – Regulatory Awareness and Infrastructure Assessment

- In your opinion, does this facility fully comply with current safety and operational regulations?

- What specific infrastructural improvements would you recommend?
- How frequently is maintenance conducted on equipment and storage installations?
- Are safety observations or near-miss events documented and addressed?

Block 4 – Documentation and Operational Traceability

- Are standard operating procedures or technical manuals available for consultation?
- Do you record your daily tasks or safety observations in any official log or checklist?
- How is feedback from audits or supervisors communicated to the team?

APPENDIX E

Cross-Classification Matrix: Operational Risk vs. Technical-Operational Performance

Unit N°	Average RPN	Risk Range	Composite KPI Score (%)	Performance Range	Final Classification
1	189	High (>180)	71,73	Moderate (65–85%)	High risk / Moderate performance
2	165	Medium (130–180)	71,60		Medium risk / Moderate performance
3	151,5		70,95		
4	140		73,60		
5	146,3		72,83		
6	138,3		72,05		
7	152,5		77,25		
8	124	Low (<130)	73,38		Low risk / Moderate performance
9	180	Medium	72,80		High risk / Moderate performance
10	157		74,25		Medium risk / Moderate performance
11	149		67,88		
12	189	High	72,43		High risk / Moderate performance
13	189		72,90		
14	180	Medium	70,18		
15	189	High	70,08		
16	189		73,58		
17	170,3	Medium	72,00	Moderate (65–85%)	Medium risk / Moderate performance
18	146		74,45		Low risk / Moderate performance
19	130		72,30		
20	148,3		71,43		Medium risk / Moderate performance

21	122,3		75,20		Low risk / Moderate performance
22	189	High	71,25		High risk / Moderate performance
23	173	Medium	73,53		Medium risk / Moderate performance
24	134		72,58		
25	145,3		70,08		
26	189	High	73,68		High risk / Moderate performance
27	129,3	Low	71,35		Low risk / Moderate performance
28	137,3	Medium	73,45	Moderate (65–85%)	Medium risk / Moderate performance
29	135		71,35		
30	148		72,93		
31	189	High	71,23		High risk / Moderate performance
32	163	Medium	72,83		Medium risk / Moderate performance
33	148,3		73,00		
34	124		71,70		Low risk / Moderate performance
35	131		70,93		Medium risk / Moderate performance
36	173		71,05		
37	149,5		72,88		
38	155		74,08		
39	146		72,13		
40	173		72,05		
41	132		71,18		
42	122	Low	72,28		Low risk / Moderate performance
43	143	Medium	69,23		Medium risk / Moderate performance
44	163		70,18		
45	140		68,35		
46	131		70,30		
47	173		70,98		
48	158		72,20		
49	138		74,68		
50	146,3		70,85		

APPENDIX F**Documented Improvements Following Risk-Based Interventions**

Unit ID	Safety Protocol Compliance (%)	Training Coverage (%)	Cylinder Inspection Rate (%)	Signage Availability (%)	Composite KPI Score (%)	Incident Rate (per 10k ops)
U01	92,1	93,7	88,8	92,9	91,8	2,14
U02	90,3	92,3	85,2	91,1	89,7	2,16
U03	88,2	90,3	87,8	89,9	89,1	2,2
U04	80,6	89,9	84,5	90,4	85	2,5
U05	80,8	90,3	86,5	90,9	87,1	2,2
U06	88,4	88,8	85,9	88,9	88	2,4
U07	89,9	90,3	88,2	89,3	89,4	2,5
U08	96,9	93,9	86,7	89,6	91,8	2,55
U09	94,5	92,9	87,5	92,9	91,9	2,6
U10	93,9	93,5	86,8	92,4	90,9	2,6
U11	88,3	89,9	89,9	89,9	89,5	2,5
U12	95,5	93,4	85,8	90,9	91,4	2,57
U13	88,2	92,9	88,4	89,9	89,8	2,45
U14	88,2	93,9	83,6	91,1	89,2	2,25
U15	92,9	90,2	85,4	90,9	89,8	2,1
U16	90,9	90,2	88,4	90,5	90	2,11
U17	86,9	90,5	85,7	89,9	88,3	2,13
U18	94,4	92,3	89,9	88,4	91,2	2,1
U19	98,8	90,2	89,3	92,2	92,6	2,1
U20	87,9	90,9	89,1	93,1	90,2	2,15
U21	88,8	92,3	88,5	90,9	90,1	2,12
U22	89,9	90,7	88,7	91,7	90,2	2,12
U23	95,9	93,9	92,9	85,4	92,5	2,5
U24	98,9	92,7	86,9	93,2	92,9	1,82
U25	86,9	90,2	88,8	90,9	89,2	2,06
U26	89,9	90,7	86,9	91,4	89,7	2,1
U27	88,4	91,7	92,9	89,8	90,7	2,2
U28	97,8	90,3	91,3	91,5	92,7	1,92
U29	89,9	90,8	92,9	90,7	91,0	2,2
U30	88,6	92,3	88,9	87,8	89,4	2,12
U31	90,1	92,9	89,9	85,8	89,7	2,1
U32	92,4	93,2	92,9	90,3	92,2	2,04

U33	95,8	90,5	91,6	85,7	90,9	2,2
U34	89,9	92,9	92,5	88,3	90,9	1,85
U35	88,9	90,2	92,9	89,9	90,4	2,14
U36	82,8	90,7	92,9	90,1	89,1	2,03
U37	87,3	90,5	88,6	90,2	89,1	1,88
U38	86,9	92,9	87,4	89,9	89,3	2,06
U39	87,5	90,8	88,9	88,5	88,9	2,13
U40	88,9	90,5	89,2	90,5	89,8	2,20
U41	92,9	91,3	89,5	89,8	90,9	2,02
U42	93,7	91,8	89,9	91,6	91,8	1,94
U43	88,4	90,9	86,8	90,3	89,1	2,1
U44	80,4	93,2	84,7	89,9	87,1	2,12
U45	82,8	92,3	87,3	88,9	87,8	2,08
U46	90,8	90,6	89,9	89,4	90,2	2,01
U47	93,6	90,9	86,7	91,2	90,6	2,01
U48	88,8	92,3	88,9	92,1	90,5	2,03
U49	90,9	90,9	89,9	89,9	90,4	2,05
U50	93,5	92,3	88,8	90,5	91,3	2,07

APPENDIX G

Operational Sensitivity Assessment of KPI Improvements

KPI Indicator	u= -5%	u= -3%	Improvement (%)	u= 3%	u= 5%
Safety Protocol Compliance	12,80	14,80	17,80	20,80	22,80
Staff Training Coverage	10,90	12,90	15,90	18,90	20,90
Cylinder Inspection Rate	12,50	14,50	17,50	20,50	22,50
Safety Signage Availability	15,80	17,80	20,80	23,80	25,80
Composite KPI Score	13,00	15,00	18,00	21,00	23,00
Incident Rate (per 10k ops)	28,60	30,60	33,60	36,60	38,60