Contribution to Quantitative Risk Analysis

CO_2 Capture Facility

Kårstø, Norway

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Contents

1.0 INTRODUCTION

Quantitative Risk Assessment (QRA) is a mathematical approach allowing the prediction of accidents and give guidance on appropriate means of minimizing them.

NORSOK standard Z-013 provides additional guidance in the preparation of QRA and provides a framework for the gathering of information in support of the analysis.

For the FEED studies, Fichtner-Gassnova document 10112936-FI-B-CON-0012 "Appendix A2 - Explanation of Deliverables", section 3.12 describes HSE deliverable H12 as Contribution to QRA.

In this context, the information that follows in section 2.0 "Discussion" provides the necessary input information tabulated with the information source and appropriate document number. This table identifies available information to support the QRA process.

The formal FEED QRA study and documentation is the responsibility of the client and owner's engineers.

2.0 DISCUSSION

2.1 OVERVIEW

The FEED HAZID Study provides the primary input to the FEED stage QRA study.

Additional documentation prepared for the FEED phase of the project provides sufficient detail to complete initial QRA activities for risk evaluation purposes. QRA undertaken during FEED cannot address all possible risk in sufficient detail to form a complete risk analysis. Further studies during the lifecycle of the EPC, construction and commission phases of project development and implementation must be undertaken to ensure proper qualification, quantification and treatment of risk.

2.2 QRA INPUT REFERENCES (PROJECT DOCUMENTS)

Information sources and project references attempt to be comprehensive in nature, to the greatest degree possible. There are additional deliverables due beyond the issue date of this document that will be available as input to risk analysis. In such cases, the document number may not be available. Such information sources are cited by their deliverable number in Fichtner-Gassnova document number 10112936-FI-B-CON-0331 "Appendix A1 - Contractor's Document Requirement List."

Table 2.2.1 below provides a detailed cross reference of available project documents that will serve as detailed input to the Quantitative Risk Analysis at the FEED stage of project development.

Table 2.2.1 QRA Input Document Cross-Reference

No.	Information/Document	Fichtner-Gassnova Doc. No.	Brief description of information source
	Project Management/Risk		
1	G9 Risk Management Document	10112936-PB-G-DOC-0003	Hazards and risks identified for the facility and the control measures used to manage them, including technical risks and costs to control risks
2	G13 Key Parameter Guarantees	10112936-PB-G-DOC-0004	Table of technical guarantees on performance of process and operation including substantiation of guarantees
	Process		
3	B1 Corrosion Evaluation	10112936-PB-M-TDO-0001	Corrosion evaluations for the main systems including maintenance requirements and worst case conditions
4	B2 Durability Report	10112936-PB-M-TDO-0002	Durability report including material selections and corrosion protection philosophy to ensure 25 year minimum life expectancy
5	B4 Process Description	10112936-PB-P-TED-0002	Process Description narrative providing overview and detail of process design and function of systems including startup, shutdown and normal operation
6	B5 Block Flow Diagram	10112936-PB-P-FLD-0001	Overall system schematic of major process system elements in a single diagram with inlet and outlet media flows
7	B6 PFDs (process and utilities)	10112936-PB-P-FLD-0002 to 0012	PFDs, showing all major process and utilities equipment and interconnections, indicating isolatable sections
8	B7 General Process Heat & Mass Balance Diagram	10112936-PB-P-HMB-0001/ 0002	Schematic and process stream compositional breakdown for all process areas; Process conditions per section (pressure, temperature, composition)
9	B12/B13/B20 P&IDs (process and utilities)	10112936-PB-P-PID-0001 through 0060 and 10112936-PB-P-DGM-0001/ 0002	Process and Instrumentation Diagrams for all process and utilities areas, including ducting. Equipment and line sizes as well as no. flanges valves etc for equipment count
10	B15 Process Datasheets	10112936-PB-P-DAS-0001 through 0008	Design and operating parameters on major equipment items for process and utilities
11	B16 Utility Unit descriptions	10112936-PB-P-TED-0003	Descriptions of the auxiliary systems and process support equipment
12	B17 Utility balances	10112936-PB-P-LST-0001	Utility balances with requirements / consumptions

No.	Information/Document	Fichtner-Gassnova Doc. No.	Brief description of information source
13	B21 Effluent Production	10112936-PB-P-TD0-0007	Continuous and non-continuous airborne, liquid and solid effluents from plant including quantities, rates of emission and composition
14	B22 Storage units and transfer systems dimensioning	10112936-PB-P-LST-0002	Storage arrangements and materials, including transport methods for chemicals and consumables
15	B23 Amine emissions abatement study	10112936-PB-P-TD0-0011	Description of design elements involved in the reduction of amine emissions to atmosphere
16	B25 Depressurization and Draining Philosophy	10112936-PB-P-TD0-0013	Depressurization and Draining descriptions for all applicable subsystems with special focus on high pressure CO2 venting and water balance
17	B26 RAM (Reliability, Availability, Maintainability) Analysis and redundancy analysis for process key components	TBD (M6 deliverable)	Reliability, Availability, Maintainability Analysis and redundancy analysis for process key components, including assessment of planned outage periods, expected forced outages, maintenance concept and required data input sources
18	B27 Energy Consumption Optimization Study	10112936-PB-P-TD0-0014	Strategies to minimize energy and utility consumption to optimize and reduce impact on overall efficiency of CCPP
19	B28 Cooling Philosophy	10112936-PB-P-TD0-0008	Evaluation of direct versus closed cooling system usage in the operation of the CCC Plant (seawater versus closed systems)
	Automation		
20	A1 Safety and Automation Systems (SAS) operating and control philosophy	10112936-PB-I-TD0-0001	SAS operating and control philosophy narrative including ESD, PSD systems, CCC Plant automatic control and critical action panel requirements
21	A2 Narrative of proposed SAS system including topology	10112936-PB-I-DRW-0001/ 0002	Technical description of proposed SAS control system solution for CCC Plant
22	A3 Function specification for Continuous Gas Monitoring and Metering system	10112936-PB-I-DRW-0003	FEED level system description, including components and operating modes of the CGMS system and its components
23	A6 Cause and Effects diagrams	10112936-PB-I-DGM-0001	Full size drawing matrix showing detailed Cause and Effects diagrams with information of system reactions as required by owner
24	A7 Fire and Gas Monitoring and Alarm System	10112936-PB-I-TED-0001	Description of Fire and Gas detection network and components, with block diagram
25	A8 Narrative of Information Management system	10112936-PB-I-D0C-0001	Brief description of plant management system, including external signal exchanges with overall site Central Control Room

No.	Information/Document	Fichtner-Gassnova Doc. No.	Brief description of information source
26	A14 Signal exchange list with external systems	10112936-PB-I-LST-0001	Main listing of signal exchange requirements between the CCC Plant and external signal sources/destinations including CCPP (Naturkraft), Gas Plant (Gassco) and CO2 storage (Gassco)
27	A16 Cable main routing scheme	10112936-PB-I-TD0-0003	Includes description of main control system cable routing within the CCC Plant
	HSE		
28	H2 WEACs	10112936-PB-S-HSE-0007	Working Environment Area Charts – shows working environment area limits for various occupational exposures and defines qualitative aspects of worker exposure; all limits and requirements of NORSOK S-002 applied
29	H3 Concept Occupational Health Impact Assessment	10112936-PB-S-HSE-0008	Application of NORSOK S-002 working requirements and technical safety requirements to FEED level of details mandated by NORSOK S-002
30	Attachment 1: H3 Chemical Health Risk Assessment (HRA) framework	10112936-PB-S-HSE-0008	Attachment 1: H3 Chemical Health Risk Assessment (HRA) framework
31	H4 Coarse Noise Study report	10112936-PB-S-HSE-0012	Coarse Noise Study on all major equipment items and areas to establish baseline case and model for noise impact, both occupational and environmental
32	H5 Fire and Explosion Strategy	10112936-PB-S-HSE-0006	Fire and Explosion Strategy Details of the fire fighting systems in the area and the activation philosophy, i.e. automatic or manual; Description of Protection Concepts and Explosion Protection Concept including intended locations of PFP, active fire protection (full area or equipment only), fire & blast walls; The type of fire and gas detection in the area, the type of response on detection, redundancy in the system.
33	H6 Escape, Evacuation and Rescue Strategy	10112936-PB-S-HSE-0015	Overall CCC Plant philosophy document based on the requirements of ISO 13702
34	H7 HAZID report and action list	10112936-PB-S-HSE-0003	FEED stage HAZID study and recommendations report
35	H8 HazOp report and output	10112936-PB-S-HSE-0013	FEED stage HazOp study and recommendations report
36	H9 Layout safety review report	10112936-PB-S-HSE-0009	FEED level narrative of overall plant layout safety and recommendation
37	H10 Hazardous Area classification drawings	10112936-PB-S-HSE-0010	Preliminary Hazardous Area Classification based on available layout details as a FEED level drawing -- IP15, 3rd edition methodologies employed

No.	Information/Document	Fichtner-Gassnova Doc. No.	Brief description of information source
38	H11 Escape Route drawings	10112936-PB-S-HSE-0011	Preliminary escape route drawings depicting the primary escape route to overall Kårstø site muster point and temporary CCC Plant mustering area
39	H13 Emissions and Discharge Data Forms	10112936-PB-S-HSE-0004	Completed data forms to the requirements of Exhibit E1.8. Data set at FEED level of development for quantification and identification of foreseeable effluents and discharges to the air, water and as waste products from the CCC Plant, including noise. Serves as input to the overall Environmental Impact Assessment
40	H3 Main Chemical MSDSs / H13 (attachment 2) Toxicity Data MSDS sheet package	10112936-PB-S-HSE-0002 / 10112936-PB-S-HSE-0004	Full listing of main chemical MSDSs / full listing of all circulating, airborne and liquid materials MSDSs for toxicity data (for worker and environment)
	Civil/Structural		
41	C1 Civil Design Philosophy	10112936-PB-C-TED-0001	Incorporates all Gassnova Civil requirements of Fichtner-Gassnova Exhibit E6.1, with any exceptions noted and is overall Civil and Structural design basis for CCC Plant
42	C20 Construction Area Layout Drawings	10112936-PB-C-DRW-0003	Drawing depicting proposed construction area including infrastructure areas
	Mechanical		
43	M1 Main Equipment and Package List	10112936-PB-R-PAL-0001	Main equipment and equipment package list, including materials
44	M2 Mechanical Datasheets	10112936-PB-R-DAS-0001	Equipment mechanical datasheets
45	M3 Driver Selection Study	10112936-PB-R-TDO-0001	Driver selection study for all main process and utility systems
46	M5 Equipment Dimensions and Weights	10112936-PB-R-TDO-0003	Equipment outlined dimensions and weights for transport and storage
	HVAC		
47	HV1 HVAC Design Basis	10112936-PB-H-TED-0001	HVAC design basis, function requirements and concept description
48	HV2 System Design	10112936-PB-H-TED-0002	HVAC System design and description narrative
	Plant Layout and Design		
49	P1 Life Cycle Cost	10112936-PB-L-TED-0002	LCC Pipe design, line sizing and materials selection to achieve the best overall lifecycle cost
50	P2 Pipe Class Selection	10112936-PB-L-TED-0001	Applicable standards or recommended alternatives
51	P3 Valve Selection	10112936-PB-L-TED-0003	Applicable standards or recommended alternatives
52	P4 Pipe Arrangement Drawings	10112936-PB-L-DRW-0001 through 0008	General large bore pipe arrangement drawings and layout drawings

No.	Information/Document	Fichtner-Gassnova Doc. No.	Brief description of information source
53	G4 3D Model Shots; General Layout and Equipment Layout Details.	10112936-PB-G-DRW-0005 through 0008	General model shots providing process area, building and structural details and perspectives; General layout overview showing major equipment and building locations and separation
	Electrical		
54	E1 Electrical Power System Design Philosophy	10112936-PB-E-TED-0001	Gassnova Electrical Design requirements for all voltage levels including the main and emergency electrical systems
55	E2 Electrical Design Basis	10112936-PB-E-TED-0002	Adoption of Gassnova philosophy with any exceptions or additions
56	E3 Overall Single Line Diagram	10112936-PB-E-DGM-0001/0002	SLD for main electrical system, including all UPS and DC subsystems
57	E5 Electrical Load Study	10112936-PB-E-TD0-0005	Maximum loading requirements under Full production, Emergency phase, Stand-by mode and UPS load. Establishes minimum full production load and any contingencies
58	E7 Emergency Generator Philosophy and Sizing	10112936-PB-E-TED-0004	All power systems and operating requirements for emergency backup power system
59	E8 Basic architecture and specification for integrated switchgear protection and control systems with interface to the Automation system	10112936-PB-E-TED-0003	Adoption of Gassnova philosophy with any exceptions or additions
60	E11 Load Flow Calculations (EDSA)	10112936-PB-E-TD0-0001	Load flow calculations for Maximum System load (including maintenance outage consideration), Minimum system load (standby mode), Emergency load and UPS load
61	E12 Short-circuit Analysis	10112936-PB-E-TD0-0002	Short-circuit Analysis to IEC 60909 with various system fault conditions and contingencies depicting simplifying assumptions
62	E13 Transient Stability Calculations (EDSA)	10112936-PB-E-TD0-0003	Study of stability under conditions of Start for largest motors, short-circuited feeders and main buss bars, reconnection/reacceleration of applicable loads, load shedding requirements, auto-transfer systems, large motor trip (on spin-up)
63	E14 Harmonic Distortion study	10112936-PB-E-TD0-0004	Documentation of completed harmonics study for various scenarios and outcomes
64	E15 Cable Main Routing Study	10112936-PB-E-TD0-0007 through 0010	Includes description of main electrical systems and subsystems cable routing within the CCC Plant

No.	Information/Document	Fichtner-Gassnova Doc. No.	Brief description of information source
65	E16 Specifications of Main Electrical Equipment	10112936-PB-E-TSP-0001	Brief overview description of main system components and arrangements
66	E18 Earthing and lightning protection plans	10112936-PB-E-TD0-0011	Design detail and specifications for Earthing and lightning protection systems/networks
	Construction		
67	S3 Constructability Report	10112936-PB-0-D0C-0001	General overview of the philosophy for constructing the CCC Plant
	Operations		
68	B32 Operations and Maintenance Philosophy	10112936-PB-0-D0C-0002	General overview of the philosophy for operating and maintaining the CCC Plant
69	B33 Operating Staff Concept	10112936-PB-0-D0C-0003	Provision of total operating staff projections, including shifts and attendance requirements
	Client Documents		
70	Exhibit E1.1 Meteorological Conditions	10112936-FI-B-C0N-0241-03	Complete, 25-year statistical treatment of Meteorological conditions, Wind rose, seismic conditions, extreme weather conditions for Kårstø site with analysis detail
71	Exhibit E8.1 HSE Requirements	10112936-FI-B-C0N-0140-05	Gassnova HSE Requirements for the CCC Plant development and operation
72	Appendix E2.10 Flare Radiation Diagram – Thermal Radiation Report	10112936-FI-B-C0N-0260-01	Radiant heat output from main Gassco flare stacks located to the south of proposed CCC Plant plot space
73	Fichtner-Gassnova Query Reply	10112936-Q-FIPB-S-0027	Statement about blast data (Fichtner-Gassnova document 10112936-Q-FIPB-S-0027)
	Miscellaneous		
74	NORSOK Z-013	N/A	Risk and Emergency Preparedness Analysis
75	Supercritical C02 research paper	N/A	Hazards from High Pressure Carbon Dioxide Releases During Carbon Dioxide Sequestration Processes, Connolly, Stephen and Cusco, Laurence, IChemE Symposium 153, 2007.

2.3 QRA FAILURE RATE DATA SOURCES

2.3.1 Overview

At the FEED stage of development of the CCC Plant design, vendor information that has been supplied does not include detailed reliability data.

Industry standard data sources and guidelines to address equipment failure rates and failure probability are enumerated below.

One particular benefit of OREDA is the presentation of safety critical reliability information on items such as smoke and heat detectors enabling assessment of emergency preparedness. OREDA is widely accepted as the standard information source for quantitative risk analysis and as such has been used extensively for safety case submission in the North Sea sector.

Application of OREDA has been so successful, that a new standard, ISO 14224, on the collection and processing of equipment failure data has been produced.

The additional information and data sources listed below are readily available and serve as further input to the QRA process to be undertaken by Gassnova directly or under the direction of a specialist consultant.

2.3.2 Sources

1. SINTEF, OREDA Handbook. 1997.

2. SINTEF Reliability Data for Safety Instrumented Systems - PDS Data Handbook, 2006 Edition.

3. Bendell, A. and A.G. Cannon, Reliability data banks. 1991, London: Elsevier Applied Science.

4. Smith, D., Developments in the Use of Failure Rate data and reliability prediction methods for hardware. 2000, Technical University of Delft: Delft.

5. Abernethy, R.B., The new Weibull handbook. 2nd ed. 1996, North Palm Beach, Fla., Houston: R.B. Abernethy ; Distributed by Gulf Pub. Co. 1 v.

6. Standards Australia, AS 3890 - Rolling Bearings - System life and reliability. 1991: Standards Australia.

7. Barringer, Weibull Database. 2001, Barringer & Associates.

8. Standards Australia, AS 3930 - Reliability and Maintainability - Introductory Guide. 1992: Standards Australia.

9. Lees, F.P., Loss prevention in the process industries : hazard identification, assessment, and control. 2nd ed. ed. Vol. Vol. 1. 1996, Oxford :: Butterworth-Heinemann.

10. Moss, T.R. and J.E. Strutt, Data Sources for reliability design analysis. Journal of process Mechanical Engineering, 1993. pp. 13-19.

11. Safety., A.I.o.C.E.C.f.C.P., Guidelines for process equipment reliability data with data tables. 1989., New York :: Center for Chemical Process Safety of the American Institute of Chemical Engineers.

12. American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS) Process Equipment Reliability Database (PERD).

13. American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS) Process Safety Incident Database (PSID).

14. Summary of Reliability data sources for Nuclear,Offshore and Chemical Industries., University of New Orleans.

15. Jensen, S., R. Stian, and E. Ostby. OREDA: A Software Tool and Database for Offshore Systems Reliability. in Offshore Mechanics and Arctic Engineering. 1993.