Effluent Production

CO_2 Capture Facility

Kårstø, Norway

Rev.	Date	Reason for Revision	By	Check	App	App	Client
0	10/10/08	Issued for Comment	BR	DM / DA			

Bechtel Power Corporation

Job No. 25474

Document No. 25474 - 000 – M5A - CN - 00001 Rev. 0

GASSNOVA

Project No. - Originator - Disc Code - Doc Type - Serial No.

10112936 – PB – P – TDO – 0007

Contents

1.0 INTRODUCTION

The CO2 Capture facilities will employ a 35 wt% aqueous solution of monoethanolamine (MEA) to capture carbon dioxide gas from the diverted flue gas stream of a combined cycle, natural gas fired turbine power plant.

The facilities are expected to generate airborne, liquid and solid wastes under normal operating conditions. As well, there is the potential for occupational exposure of workers under normal shutdown, routine maintenance and repair conditions.

2.0 EFFLUENTS

2.1 Airborne Effluent

Predictable continuous airborne effluent is expected from the two (2) Absorber Towers from process simulations. Table 2.1 shows these streams, which are enumerated 103/203 in the normal case Heat and Mass Balance (Bechtel / Owner Doc. Number: 25474-000-M5A-CN-00001 / 10112936-PB-P-HMB-0001):

Table 2.1 Airborne Effluent

Component	ppm (vol)	kg/h
MEA	< 1	2.5
NO	< 4	4.23
NO2	< 1	1.057
Ammonia	< 4	2.24
Formaldehyde	< 1*	*
Acetaldehyde	< 1*	*
Piperazine	< 1*	*

Notes: * this effluent has not been quantified in the Heat and Mass Balance but is expected in quantities less than 1 ppm at the vent stack outlet.

Total airborne venting is simulated to 1,028,980 Sm^3/h (per vent). The Absorber Towers are designed to vent all uncaptured gases to atmosphere through the top through a circular vent stack. Discharge is expected to dilute the composition with air. The remaining gases to be vented are Carbon Dioxide, Oxygen, Nitrogen, Water Vapor and Argon.

The risk is mitigated through this dilution effect, at which point the presence of these low solubility gases will diminish to "insignificant" Chemical Exposure Categories per NORSOK S-002 risk evaluation matrix (see Risk Categories and Matrix in Annex A).

Continuous emissions monitoring (CEM) equipment is to be housed in a small shelter. Under normal operating conditions, all sampling points will be automatic to the Central Control Room or in closed system components.

2.2 Maintenance or Other Equipment Access Operational Exposure

Under normal operating conditions for the plant, it is expected that process systems will function as normally closed designs.

Table 2.2 shows the expected circulating process components in stream compositions.

Table 2.2 Process Stream Composition Assessment

Circulating Chemicals	Norway Pollution In the Workplace OEL Limit (ppm)	Comment
Monoethanolamine (MEA) [C2H7NO / H2NCH2CH2OH]	1	Miscible
Soda Ash [Na2CO3]	None Listed	Miscible
Sulfur Dioxide [SO2]	0.8 (2 mg/m^3)	<0.25 ppm max
Nitric Oxide [NO]	25	< 4 ppm max
Nitrogen Dioxide [NO2]	0.6 (1.1 mg/m^3)	0.87 ppm max (see below)
Ammonia [NH3]	25	Miscible
Carbon Dioxide [CO2]	5000	(see below)
Oxalic Acid [C2H2O4/(COOH)2]	0.27 (1 mg/m^3)	Solubility > 9.5 mg/ml
Acetic Acid [C2H4O2/CH3COOH]	10	Miscible
Formic Acid [HCOOH]	5	Miscible
Thiovanic Acid [C2H4O2S / HSCH2COOH]	1	Highly soluble

During system maintenance and unit turnarounds, it is expected that standard shutdown procedures will be maintained to ensure all systems remain normally closed until all harmful process chemicals normally in circulation are flushed to a closed system safely. This may include water and / or steam flushing to reduce potentially harmful chemicals to below the OEL.

The presence of NOx, SO2 and CO2 in concentrations of concern can be mitigated procedurally leading into shutdown by stopping flue gas flow to the capture plant, at which point the presence of these low solubility gases will diminish to "insignificant" Chemical Exposure Categories per NORSOK S-002 risk evaluation matrix (see Chemical Risk Categories and Matrix in Annex A below).

Table 2.3 Process Streams Risk Assessment

Component	Stream Mass Fraction	EU Symbol	Risk Phrase	Concentration Threshold (wt%)
Monoethanolamine (MEA) [C2H7NO / H2NCH2CH2OH]	1, 0.376***	Xn C	R20/21/22 R34	>25%
Soda Ash [Na2CO3]	0.5****	Xi	R36	N/A
Sulfur Dioxide [SO2]	0.0000002	Xi	R36/37/38	<< 5%
Nitric Oxide [NO]	0.0000035	T C	R23/R24/R25 R34	**
Nitrogen Dioxide [NO2]	0.0000009	Xn	R20	<< 0.5%
Ammonia [NH3]	0.0000218	Xi	R35	<< 5%
Carbon Dioxide [CO2]	0.9997	None	None	N/A
Oxalic Acid [C2H2O4/(COOH)2]	0.000019	Xi	R36/38	< <25%
Acetic Acid [C2H4O2/CH3COOH]	0.000052	Xi	R36	N/A
Formic Acid [HCOOH]	0.000027	Xi	R36/38	< <10%
Thiovanic Acid [C2H4O2S / HSCH2COOH]	0.000001	Xn	R20/21/22	< <2%

Notes: Concentration thresholds from Norwegian "Stofflisten" database for Risk phrase reductions to mitigate risk based on concentration threshold

** circulating concentration less than 4 ppm under normal case

*** fresh amine assumed to be 100% amine in simulation. Fresh amine concentration to be determined. In circulating streams, max concentration is37.6 wt.% under normal case

**** soda ash injection to reclaimer assumed to be 50 wt. %, via metering pump

The remaining chemicals in circulation are either fully water miscible or sufficiently soluble that water flushing practices can be used to a closed system prior to opening equipment for services. Dilution of residual quantities of components listed in Table 2.3 can be reduced below the "moderate" Chemical Exposure Categories per NORSOK S-002 risk evaluation matrix (see Chemical Risk Categories and Matrix see Annex A below).

Shutdown and flushing procedures must also be applied to all filters, pumps and other equipment in the amine plant to prevent occupational exposure during routine filter basket removal and cleaning (see section 2.4 Solid Discharges below).

Use of PPE will be required manage risk in the form of protective clothing, eyewear, gloves, footwear and (where appropriate) filter masks or respirators. Sampling shall only be undertaken in closed systems by design to limit worker exposure under operating conditions.

2.3 Liquid Effluent

Liquid amine at any concentration is not intended for disposal in any sewer or bodies of water. In general, water generated from process internal condensates, intercoolers and aftercoolers are recycled to the internal process systems. Some operations could require disposal of a water effluent.

Any contaminated process stream materials will be handled through a dedicated sump (TK-103) and either recycled (via pumps P-112A/B) back to the process internally or pumped for disposal to external facilities.

During system maintenance and unit turnarounds, it is expected that standard shutdown procedures will be maintained to ensure all systems remain normally closed until all harmful process chemicals normally in circulation are flushed to a closed system safely. This may include water, steam and/or chemical flushing to reduce potentially harmful chemicals to below the OEL prior to opening equipment. Use of PPE will be required.

2.4 Solid Discharges

Process simulation and calculation (reference 25474-000-M5C-CN-00001) has quantified the Amine Reclaimer (X-102) waste production at 170.5 kg/h at normal case CO2 capture facility operations simulation.

It is expected that the reclaimer will generate a continuous residue (i.e. sludge) that will require collection and removal as hazardous waste on a routine basis. The following listing of materials could be in the waste material composition:

Table 2.4 Solid Discharge Composition Risk Factors

Component	EU Symbol	Risk Phrase	Concentration Threshold (wt%)
Ammonia [NH3]	Xi	R35	< 5%
Soda Ash [Na2CO3]	Xi	R36	N/A
Acetic Acid [C2H4O2/CH3COOH]	Xi	R38/38	< 10%
Monoethanolamine (MEA) [C2H7NO / H2NCH2CH2OH]	Xi	R36/37/38	< 10%
N-acetylethanolamine [C4H9NO2]	Xi	R36/37/38 R41	N/A
N-glycylglycine (C4H8N2O3)	Xi	R36	N/A
N-(hydroxyethyl)-succinimide [C6H9NO3]	Xi	R36/37/38	N/A
N-(2-hydroxyethyl)-lactamide [C5H11NO3]	No Info	No Info	No Info
1-(2-hydroxyethyl)-2-imidazolidinone [C5H10N2O2]	Xi	R36/37/38 R41	N/A
N,N-diacetylethanolamine [C6H11NO3]	No Info	No Info	No Info
Propionic acid [C3H6O2]	C	R34	<25%
N-butyric acid [C4H8O2]	C	R34	N/A
2,6-dimethyl-4-pyridinamine [C7H10N2]	No Info	No Info	No Info
2-imidazolecarboxaldehyde [C4H4N2O]	Xi	R36/37/38	N/A
1-methyl-2-imidazolecarboxaldehyde [C5H6N2O]	Xi	R36/37/38	N/A
2-oxazolidone [C3H5NO2]	Xn	R22 R36 R43	N/A

Notes: Concentration thresholds from Norwegian "Stofflisten" database for Risk phrase reductions to mitigate risk based on concentration threshold

EU Symbol and Risk Phrases sourced from MSDS listings of Sigma-Aldrich Norway AS and modified as permissible under Norwegian Stofflisten based on CAS number lookup

Chemical listing depicted in the table above based on source: "B.R. Strazisar, C.M. White, Degradation of Monoethanolamine Use in Carbon Dioxide Capture from Flue Gas of a Coal-fired Electric Generating Station, (National Energy Technology Laboratory Clean Air Technology Division, undated)."

Composition of the waste product will vary over time. The sludge will require collection and disposal at an offsite industrial waste disposal facility. Further treatment of the residue may be required prior to removal to reduce risk levels.

Under conditions requiring entry into the reclaimer for maintenance or repair, the occupational exposure is dictated by the potential presence of any chemical listed above. Occupational exposure risk is present from effluent material that indicates a NORSOK S-002 Chemical Health Hazard Category of 3 (Moderately Serious) or lower with the exception of 2-oxazolidone [C3H5NO2], which is a Serious Exposure (Risk level 4) due to sensitizing properties.

Removing bulk waste accumulation prior to reclaimer entry, safe shutdown procedures through use of flushing and steam out operations will reduce the Chemical Exposure Categories of the listed chemical to thresholds of below moderate exposure. The use of additional PPE based on the Safety Phrases for listed material can mitigate the occupational exposure.

For filter solid wastes, it is expected that this material will require collection to sealed drums or containers for subsequent disposal.

ANNEX A

Table A.1 Occupational Health Hazard Risk Matrix

Risk Estimation Matrix for Long-Term and Average Exposures

A	1	2	3	4	5	12	
Very Serious	5	10	15	20	25	60	5
Serious	4	8	12	16	20	48	4
Moderately Serious	3	6	9	12	15	36	3
Less Serious	2	4	6	8	10	24	2
Insignificant	1	2	3	4	5	12	1
B	Insignificant Very Low	Low	Moderate	High	Very High	Extremely High	

Source: NORSOK S-002

A – Chemical Health Hazard Category (column)

B – Chemical Exposure Category (row)

Table A.2 Chemical Health Hazard Categories

Health Hazard Categories		Risk (R) or Safety (S) Phrases
VERY SERIOUS		
Very Toxic (T+)		
-	Acute Toxicity	R26, R27, R28
-	Irreversible Effects	R39
Toxic (T)		
-	Carcinogens Cancer1 and Cancer 2	R45, R49
-	Mutagens Mut1 and Mut2	R46
-	Toxic to reproduction/teratogen Rep1 and Rep2	R60, R61
Explosive (E)		R44
SERIOUS		
Toxic (T)		
-	Acute Toxicity	R23, R24, R25, R23/24/25
-	Chronic Effects	R48
Corrosive (C)		R35
Harmful (Xn)		
-	Cancer3	R40
-	Mut3	R68
-	Rep3	R62, R63
-	Sensitizing	R42, R43
Flammable		R10
Bioaccumulation		R33
Harmful to breast-fed babies		R64
MODERATELY SERIOUS		
Corrosive (C)		R34
Harmful (Xn)		
-	Acute Toxicity	R20, R21, R22, R65
-	Harmful by contact or ingestion	R20/21/22, R21/22
Irritant (Xi)		R41
Feel unwell after inhalation or contact – seek medical attention		S45
LESS SERIOUS		
Irritant (Xi)		R36, R37, R38, R66, R67
Avoid Inhalation		S22, S23
Avoid Contact		S24, S25, S26, S24/25
Response Following Contact with Clothing/Skin		S27, S28
Use Personal Protective Equipment		S36, S37, S38, S39, S36/37/39
Ventilation Required		S9, S51, S52
Keep Away from Sources of Ignition		S16
INSIGNIFICANT		
Unclassified		

Source: NORSOK S-002

Per 67/548/EEC Risk and Safety Phrases

The Carcinogenic categories are:

R45	1 - Substances known to be carcinogenic to man.
R49	2 - Substances which should be regarded as if they are carcinogenic to man
R40	3 - Substances that cause concern for man owing to possible carcinogenic effects but in respect of which the available information is not adequate for making a satisfactory assessment.

The Mutagenic categories are:

R46	1 - Substances known to be mutagenic to man.
R46	2 - Substances that should be regarded as if they are mutagenic to man
R68	3 - Substances that cause concern for man owing to possible mutagenic effects.

The Toxic to Reproduction categories are:

R60	1 - Substances known to impair fertility in humans and substances known to cause developmental toxicity in humans.
R61	2 - Substances that should be regarded as if they impair fertility in humans and substances that should be regarded as if they cause developmental toxicity to humans.
R62, R63	3 - Substances that cause concern for human fertility and substances that cause concern for humans owing to possible developmental toxic effects.

Table A.3 Chemical Exposure Categories

Exposure categories	
Qualitative	**Quantitative**
Extremely high	>> Reference value
Very high	≥ Reference value
High	50 % to 100 % of reference value
Moderate	10 % to 50 % of reference value
Low	< 10 % of reference value
Insignificant/very low	~ Background

Source: NORSOK S-002