

## CALCULATION COVER SHEET

PROJECT CO2 KARSTO	JOB NO. 25474	CALC NO. Bechtel:25474-000-M4C-CN-00003 Owner:10112936-PB-P-TDO-0003	SHEET 1
SUBJECT: CO2 Absorber sizing calculations		DISCIPLINE: Process	

<b>CALCULATION STATUS</b>	PRELIMINARY X	CONFIRMED	SUPERSEDED	VOIDED
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COMPUTER PROGRAM/TYPE	SCP		MAINFRAME PC		PROGRAM NO.	VERSION/ RELEASE NO.
	YES	NO	YES	NO	Promax KG-TOWER Sulcol	2 3.2 1.05
	X	<input type="checkbox"/>		X <input type="checkbox"/>		

Use of these calculations by persons, without access to pertinent factors and without proper regard for their purpose, could lead to erroneous conclusions. Should it become necessary to use any of these calculations in your work in the future, it is suggested that the calculations be reviewed with authorized Bechtel personnel to ensure that the purposes, assumptions, judgments and limitations are thoroughly understood. Bechtel cannot assume responsibility for the use of these calculations not under our direct control.

- Reference Data:** 1.
- 1) Bechtel Process Engineering Design Guide - Tower Internals
  - 2) Bechtel Standard Drawing No. B-501
  - 3) Bechtel Process Engineering Design Guide - Separators
  - 4) Heat & Material Balance Normal Case

**Design Basis:** CO2 Kårstø - Exhibit E0 - Design Basis

**Remarks:**  
This document provides the sizing calculation for the CO2 Absorber and its wash water section

**Comments**

1	Issued for Information Including Comments <b>P0045</b>	7	7	MJC	HS/DM	ADB/BR	12-Nov-08
0	Issued For Deliverable Milestone Schedule M2	7	7	HS	MJC/DM	ADB/BR	7-Oct-08
NO.	REASON FOR REVISION	TOTAL NO. OF SHEETS	LAST SHEET NO.	BY	CHECKED /APPROVED	REVIEWED /ACCEPTED	DATE

### RECORD OF REVISIONS



# CALCULATION SHEET

CALC NO. Bechtel:25474-000-M4C-CN-00003 Owner:10112936-PB-P-TDO-0003  
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## 1. PURPOSE OF CALCULATION:

Sizing of the CO2 Absorber, MV-101, MV-102 based on the design basis and bechtel standard guides

## 2. METHODOLOGY:

Heat and material balances developed for Normal case - reclaimer and without reclaimer operation by Bantrel were used in this calculation. All other cases are within +10% of the Normal case. The Summer Turndown case is 60% of the Normal case and so 60% will be taken as Turndown Column Diameter was calculated using two programs KG tower and Sulcol. Using conservative approach larger diameter was used to fix the diameter of the column.

The height of the column was worked out based on:

Residence time of 6 mins for rich amine in column bottom (LLL - HLL).

Residence time of 5 mins for wash water in pan (LLLL - HHLL). (3 mins LLL-HLL)

## 3. COLUMN DIAMETER:

### 3.1 Software calculation

Basis of flows for diameter calculation

Largest liquid flow - stream 300 divided for 2 absorbers

Largest vapour flow - stream 100/200

The results of the KG-Tower and Sulcol are tabulated below:

Program	Column Tag No.	Diameter mm	Internals	Flooding Limit %	System Factor	HETP Height m
KG Tower	MV-101/102	#	FLEXIPAK 250 YHC structure packing	0.8	0.8	2.0
Sulcol	MV-101/102	#	Mellapak 170X structure packing	0.8	0.8	2.0

The selected column diameter is 11802 mm say 11810 mm

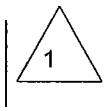
# - values obtained from vendor software and subject to confidentiality agreement between Bechtel and vendor

The turndown capability of the packing is 50% of the Normal Case and so satisfies the 60% turndown requirement specified above.

For the wash water section, a system factor of 1.0 is applied.

For the top wash water bed, stage 1, structured packing is installed but the capacity requirements are lower, which may result in a different selection to that listed above for the bulk of the column

The liquid load of the top bed is 0.26 m3/h/m2 which exceeds the minimum loading of 0.2 m3/h/m2.





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## 4. COLUMN HEIGHT:

### 4.1 Liquid Levels:

Flow Rate 1392443 kg/h  
 Density 1151 kg/m<sup>3</sup>  
 Volume Flow 1209 m<sup>3</sup>/h  
 Column Diameter 11.81 m  
 CSA 109.5 m<sup>2</sup>

Variations in absorber liquid level will reflect the overall water balance in the amine system and allow the operator to adjust lean amine or water wash temperatures in order to hold levels constant at a given feed gas flow and temperature. Note that a liquid equalizing line between the absorbers dampens liquid level changes between the two absorbers.

	Calculated mm	Actual mm	Vol (m <sup>3</sup> )	Hold up Vol (m <sup>3</sup> )	Hold up min	
HHLL (from BTL)	1772	1800	194.1	20.2	1	1 min holdup time between HHLL and HLL
HLL (from BTL)	1588	1600	174.0	120.9	6	6 minutes required
NLL (from BTL)	1036	1050	113.5	100.8		
LLL (from BTL)	484	500	53.0	20.2	1	1 min holdup time between LLLL and LLL
LLLL (from BTL)	300	300	32.9			



### 4.2 Liquid Levels on Wash water draw-off:

Vapor Flow Rate 1206228 kg/h (Stream 103 in H&B balance)  
 Density 110756 kg/m<sup>3</sup>  
 Volume Flow 1121405 m<sup>3</sup>/h  
 Column Diameter 11.81 m  
 CSA Tower 109.5 m<sup>2</sup>  
 Chimney area= % of X-sec area 20% (Bantrel B-501-SI, note 2)  
 Total CSA Chimney area 21.9 m<sup>2</sup>  
 Diameter of 1 chimney 5.3 m  
 Velocity through total chimney area 14.22 m/s

Limiting the chimney diameter to 1.0 m  
 CSA per chimney 0.8 m<sup>2</sup> (28 Chimneys)  
 Clearance b/t plate and chimney to limit the gas velocity to 14.22 0.250 m clearance= vapor exit area = chimney area (Bantrel B-501-SI, note 3)

Excess water draw rate 1436723 kg/h (Stream 101+102)  
 Density 9877550 kg/m<sup>3</sup>  
 Volume Flow 1455 m<sup>3</sup>/h

**Chimney height = controllable height + Buffer volume**  
 5% of packed volume 32.9 m<sup>3</sup>  
 Buffer Height 375 mm  
 Total chimney height 1911 mm (Buffer + level control height)

### Level Control on draw off tray:

	mm	min
HHLL	1536	5.0
HLL	1259	4.0
NLL		
LLL	429	1.0
LLLL	152	

152mm -6"min



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## 4.3 Column

Height above Demister	1181	mm	> 305 mm or 10% D	Bantrel B-505-SI	
Demister	150	mm			
Nozzle N2	152.4				1
Manway 30"	762				
Liquid distributor					
From Demister to Bed1	1520	mm			
Bed 1 height	2000	mm			
Lattice support	1500	mm			
Nozzle N3	508				1
Manway 30"	762				
Liquid distributor					
From Lattice support to Bed2	1520	mm			
Bed 2 height	4000	mm			
Lattice support	1500	mm			
Height above chimney	750	mm			
Clearance between plate and top	250	mm	min. 12" Bantrel B-504-IMP or 0.75 dr		
Chimney Height	1911	mm			
Nozzle N4	508				
Manway 30"	762				
Depth for Draw-off par	762		for 20" nozzle, 30" 3DG B10017		
From draw-off tray to Demister	1181	mm	> 305 mm or 10% D	Bantrel B-505-SI	
Demister height	150				
From Demister to Bed3	1520				
Bed 3 height	2000	mm			
Lattice support	1500	mm			
Nozzle N5	406.40				
Manway 30"	762				
Liquid distributor					
From Lattice support to Bed4	1520	mm			
Bed 4 height	8000	mm			
Lattice support	1500	mm			
Nozzle N6	203.20				
Manway 30"	762				
Liquid distributor					
From Lattice support to Inlet duct	1500	mm			
Inlet Duct	6200	mm	Plot Plan		
Height above HHLL to Inlet Duct	1157	mm			1
Nozzle N9 deleted					
Height for level control	1800	mm			
Total height (T/T)	44810	mm			



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## 5.0 Column Tray Efficiencies:

	Theoretical Stages	HETP	Height m
Wash Water	3	2.00	6.0
CO2 Absorber	5	2.00	10.0

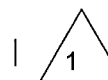
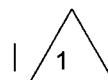
## Column Tray Section

Bed 1	2000	mm	Wash water
Bed 2	4000	mm	Wash water
Bed 3	2000	mm	Amine
Bed 4	8000	mm	Amine

## 6.0 Pressure Drops:

Pressure Drop through Packed beds	3.43	mbar/m
Tota Height of Packed Beds	16	m
Total Pressure drop	54.88	mbar

	Mass flow (Kg/hr)	Density (Kg/m3)		Velocity (m/s)	Pressure Drop	kPa	Assumed
		Liquid	Gas				
outlet nozzle	1206228		1.08	18.97	0.097	kPa	
top demister	1206228		1.08	2.84	0.437	kPa	
Chimney Tray	1206228		1.08	14.22	0.435	kPa	
mid demister	1206228		1.08	2.84	0.437	kPa	
Inlet Duct					1.000	kPa	
Packed Bed	1296910		1.139		5.488	kPa	
liquid distributor	1296910		1.139	2.89	0.019	kPa	
$\Delta P$					7.91	kPa	







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
## 7.0 Nozzle Sizes.

Min stack exit velocity should be 1.5 times expected wind velocity, which rarely exceeds 12 m/s


### N1: Vapor Outlet nozzle

Case	Normal Flow / No Margin				
Flow (Stream 103/203)	1206228.0 KG/HR				
Density	1.08 KG/M <sup>3</sup>				
Nozzle Diameter	180.00 IN	4572	mm		
No of nozzles	1.00				
Velocity	18.97 M/S			Target 18 m/s	
	62.25 FT/S			50-150 ft/s	
rv2	387.2401 Pa				

### N2: Process Water Nozzle

Case	Normal Flow / No Margin				
Flow (Stream 107/207)	27315.0 KG/HR				
Density	997.89 KG/M <sup>3</sup>				
Nozzle Diameter	6.00 IN	152	mm		
No of nozzles	1.00				
Velocity	0.42 M/S				
	1.37 FT/S			5-10 ft/s	

### N3 : Wash Water Nozzle

Case	Normal Flow / No Margin				
Flow (Stream WWC)	1360777.1 KG/HR				
Density	999.86 KG/M <sup>3</sup>				
Nozzle Diameter	20.00 IN	508	mm		
No of nozzles	1.00				
Velocity	1.87 M/S				
	6.12 FT/S			5-10 ft/s	

### N4 A/B: Wash Water Draw Off Nozzle

Case	Normal Flow / No Margin				
Flow (Stream 101+102/201+202)	1436722.5 KG/HR				
Density	987.76 KG/M <sup>3</sup>				
Nozzle Diameter	20.00 IN	508	mm		
No of nozzles	2.00				
Velocity	1.00 M/S				
	3.27 FT/S			max 3.8 ft/s for 20" Draw	

### N5: Lean Amine Nozzle

Case	Normal Flow / No Margin				
Flow (Stream 104/204)	1098654.2 KG/HR				
Density	1086.81 KG/M <sup>3</sup>				
Nozzle Diameter	16.00 IN	406	mm		
No of nozzles	1.00				
Velocity	2.16 M/S				
	7.10 FT/S			5-10 ft/s	

### N6: Semi Lean Amine Nozzle

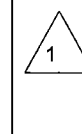
Case	Normal Flow / No Margin				
Flow (Stream 105/205)	273713.7 KG/HR				
Density	1142.46 KG/M <sup>3</sup>				
Nozzle Diameter	8.00 IN	203	mm		
No of nozzles	1.00				
Velocity	2.05 M/S				
	6.73 FT/S			5-10 ft/s	

### N8/N10: Rich Amine Nozzle/ Equalising Line Nozzle

Case	Normal Flow / No Margin				
Flow (Stream 106/206)	1392443.7 KG/HR				
Density	1151.40 KG/M <sup>3</sup>				
Nozzle Diameter	24.00 IN	610	mm		
No of nozzles	1.00				
Velocity	1.15 M/S				
	3.78 FT/S			2-4 ft/s	

### N9A/B: Overflow Nozzle

DELETED  
Overflow will be protected by instrumentation



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**8.0 Sketch**

**CO2 ABSORBER COLUMN**  
 TL - TL = 44,310 mm  
 ID = 11,810 mm

