

### CALCULATION COVER SHEET

PROJECT CO2 KARSTO	JOB NO. 25474	CALC NO. BECHTEL: 25474-000-M4C-CN-00005 OWNER: 10112936-PB-P-TDO-0005	SHEET 1
VESSEL SIZING		DISCIPLINE PROCESS	
Evaluation of vessels MV-201, MV-202, MV-203, MV-104, MV-105 and MV-106 sizes.			
CALCULATION STATUS DESIGNATION	PRELIMINARY	CONFIRMED	SUPERSEDED
	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

COMPUTER PROGRAM/TYPE	SCP	MAINFRAME	PC	PROGRAM NO.	VERSION/RELEASE NO.
	<input checked="" type="radio"/> YES <input type="radio"/> NO	<input type="radio"/>	<input checked="" type="radio"/>	N/A	N/A

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.

**REMARKS :**

1. The design is based on Bechtel Design Guide for Separators, 3DG B010 00010.
2. Vessel sizing calculations have been performed using Bechtel's Vessel/Nozzle Sizing Spreadsheet (V-calc) v1.3 26 Feb 2008.
3. 110% normal vapour and liquid flowrates based on the Promax simulation for normal operation with the Reclaimer on are shown. Vessel sizing adequate for all cases.
4. Sized for 150 microns without demister, 500 microns with demister.
5. CO2 Surge Drum sized for venting 5% CO2 vapour in upset conditions.

0	Issued for Deliverable Milestone Schedule M2	7	7	JS	MJC/DM	ADB/BR	8-Oct-08
REV. NO.	REASON FOR REVISION	TOTAL NO. OF SHEETS	LAST SHEET NO.	BY	CHECKED/ APPROVED	REVIEWED/ ACCEPTED	DATE
<b>RECORD OF REVISIONS</b>							

CLIENT NAME: GASSNOVA  
 PROJECT NAME: CO2 KARSTO  
 BECHTEL JOB NO. 25474

VESSEL SIZING v 1.3 26 February 2008		EQUIP NO	MV-201	MV-202	MV-201	MV-202	
EQUIPMENT NAME			Semi-Lean Flash Drum	Stripper Reflux Drum	Semi-Lean Flash Drum SI UNITS	Stripper Reflux Drum SI UNITS	SI UNITS
CASE							
<b>INPUT PARAMETERS</b>							
OPERATING PRESSURE	PSIA	34.8	26.0	240	179	kPaa	
OPERATING TEMPERATURE	F	236.7	119.7	113.7	48.7	°C	
Wv = VAPOR RATE	LB/HR	23,161	317,912	10505.66	144202.3	kg/h	
Dv = VAPOR DENSITY	LB/FT3	0.136	0.178	2.18	2.858	kg/m3	
Rv = VAPOR VISCOSITY	CP	0.017	0.016	0.000017	0.00001617	Pa.s	
WI = HC LIQUID RATE	LB/HR	1,327,557	183,533	602169.7	83249.1	kg/h	
DI = HC LIQUID DENSITY	LB/FT3	70.135	61.686	1123.78	988.4	kg/m3	
RI = HC LIQUID VISCOSITY	CP	0.700	0.536	0.0007	0.00053625	Pa.s	
Ww = WATER RATE	LB/HR	-	-	0	0	kg/h	
Dw = WATER DENSITY	LB/FT3	-	-	0	0	kg/m3	
Rw = WATER VISCOSITY	CP	-	-	0	0	Pa.s	
<b>VESSEL DIMENSIONS</b>							
ORIENTATION (1 - VERTICAL, 2 - HORIZONTAL)			1	1			
<b>DRUM SIZE</b>							
D = INSIDE DIAMETER	FT	10.00	12.00	3.048	3.6576	m	
L = LENGTH (TANG-TANG)	FT	30.00	18.00	9.144	5.4864	m	
Ln = LENGTH (NOZ-NOZ)	FT	30.00	18.00	9.144	5.4864	m	
La = AVAIL. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A				
HLL FROM BOTTOM TANG (FOR HC)	FT	27.00	15.00	8.2296	4.572	m	
NLL FROM BOTTOM TANG (FOR HC)	FT	13.75	7.75	4.191	2.3622	m	
LLL FROM BOTTOM TANG (FOR HC)	FT	0.50	0.50	0.1524	0.1524	m	
<b>WATER BOOT SIZE</b>							
Db = INSIDE DIAMETER	FT	N/A	N/A			m	
Lb = LENGTH (TANG-TANG)	FT	N/A	N/A			m	
HLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A			m	
NLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A			m	
LLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A			m	
LIQUID RESIDENCE TIME TARGET	MIN	6.0	6.0				
<b>OPTIONS</b>							
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
D = DROPLET/PARTICLE SIZE FOR SEPARATION	MICRONS	500.00	500.00				
****BASED ON PARTICLE SIZE SEPARATION (check for HC liq/water)****							
D = DROPLET SIZE FOR SEPARATION	MICRONS	127.00	127.00				
Vsd = DESIGN SETTLING VELOCITY LIMIT	IN/MIN	10.0	10.0	0.004233333	0.004233333	m/s	
<b>WATER BOOT SIZE CHECK</b>							
D = DROPLET SIZE FOR SEPARATION	MICRONS	127.00	127.00				
Vsd = DESIGN SETTLING VELOCITY LIMIT	IN/MIN	10.0	10.0	0.004233333	0.004233333	m/s	
<b>MIST PAD</b>							
K = MIST PAD SIZING FACTOR		0.30	0.30				
<b>RESIDENCE TIME AND LIQUID DOWNWARD VELOCITY CHECK</b>							
VESSEL SURGE VOLUME FROM HLL-LLL, incl. head for horizontal	GALLONS	15569.245	12267.390	58.936	46.437	m3	
<b>FOR VERTICAL DRUM</b>							
HC RESIDENCE TIME HLL-NLL	MIN	3.3	16.5				
HC RESIDENCE TIME NLL-LLL	MIN	3.3	16.5				
TOTAL HC RESIDENCE TIME (HLL-LLL)	MIN	6.6	33.1				
LIQUID DOWNWARD VELOCITY	FT/MIN	4.0	0.4				
LIQ FILL-UP FROM HLL TO TOP, incl. top head	MIN	1.2	11.4				
<b>FOR HORIZONTAL DRUM</b>							
Hh = RISE OF HLL	FT	N/A	N/A				
Ah = LIQ FLOW (SEGMENT) AREA @ HLL	FT2	N/A	N/A				
Hi = RISE OF LLL	FT	N/A	N/A				
AI = LIQUID FLOW (SEGMENT) AREA @ LLL	FT2	N/A	N/A				
NET LIQUID CSA (HLL-LLL)	FT2	N/A	N/A				
HC RESIDENCE TIME (HLL-LLL), incl. head	MIN	N/A	N/A				
LIQ FILL-UP FROM HLL TO TOP, incl. head	MIN	N/A	N/A				
<b>FOR WATER BOOT</b>							
WATER RESIDENCE TIME (HLL-LLL)	MIN	N/A	N/A				
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
D = DROPLET/PARTICLE SIZE FOR SEPARATION	MICRONS	500.00	500.00				
CR <sub>e</sub> <sup>2</sup> = 3.355E-9*Dv <sup>2</sup> *D <sup>3</sup> *(DI-Dv)/Rv <sup>2</sup>		13820.13	17596.76				
C = DRAG COEFFICIENT (CURVE FIT DATA)		0.95	0.89				
Vs = SETTLING VELOCITY	FT/SEC	6.16	5.22	1.877654947	1.59241672	m/s	
= 0.01186*(D/C) <sup>0.5</sup> *(DI/Dv-1) <sup>0.5</sup>							
L / D = LENGTH (NOZ-NOZ) TO DIAMETER RATIO		1.00	1.00				
Va = ALLOW VELOCITY = 85% * (L/D) * Vs	FT/SEC	5.24	4.44	1.596006705	1.35355421	m/s	
Kv = Va / (DL/DV-1) <sup>0.5</sup> (EQUIVALENT)	FT/SEC	0.23	0.24	0.070362937	0.07289021	m/s	
Ar = CSA REQ'D FOR VAPOR FLOW = V / Va	FT2	9.031	111.487	0.838981329	10.3574887	m2	
IDr = DIAMETER REQ'D FOR VERTICAL DRUM	FT	3.39	11.91	1.033549324	3.6314686	m	
Aa = AVAIL VAP PHASE CSA @ HLL FOR HORIZ	FT2	N/A	N/A				
VESSEL SIZE CHECK		OK	OK				

CLIENT NAME: GASSNOVA  
 PROJECT NAME: CO2 KARSTO  
 BECHTEL JOB NO. 25474

VESSEL SIZING v 1.3 26 February 2008		EQUIP NO	MV-201	MV-202	MV-201	MV-202	
EQUIPMENT NAME			Semi-Lean Flash Drum	Stripper Reflux Drum	Semi-Lean Flash Drum SI UNITS	Stripper Reflux Drum SI UNITS	SI UNITS
CASE							
****BASED ON PARTICLE SIZE SEPARATION (check for HC liq/water)****							
WATER SETTLING WITH LEVEL							
D	= DROPLET SIZE FOR SEPARATION	MICRONS	N/A	N/A			
Vs	= SETTLING VELOCITY	IN/MIN	N/A	N/A			
	= $[.334 \cdot D^{.2} / 127 \cdot 2 \cdot (D_w - D_l) / R_w]$						
Vsd	= DESIGN SETTLING VELOCITY (RECOMMENDED < 10)	IN/MIN	N/A	N/A			
La	= AVAIL. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
WATER SETTLING WITH LEVEL @ LLL							
V	= LIQUID (HC + H2O) HORIZONTAL VELOCITY	FT/MIN	N/A	N/A			
Hl	= LIQUID HEIGHT @ LLL	INCH	N/A	N/A			
Lr	= REQ. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
	= $[V \cdot H_l / V_{sd}]$						
	CHECK LLL HEIGHT	-----	N/A	N/A			
WATER SETTLING WITH LEVEL @ HLL							
V	= LIQUID (HC + H2O) HORIZONTAL VELOCITY	FT/MIN	N/A	N/A			
Hh	= LIQUID HEIGHT @ HLL	INCH	N/A	N/A			
Lr	= REQ. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
	= $[V \cdot H_h / V_{sd}]$						
	CHECK HLL HEIGHT	-----	N/A	N/A			
WATER BOOT SIZE CHECK							
	WATER RESIDENCE TIME (HLL-LLL)	MIN	N/A	N/A			
D	= DROPLET SIZE FOR SEPARATION	MICRONS	N/A	N/A			
Vs	= SETTLING VELOCITY	IN/MIN	N/A	N/A			
	= $[.334 \cdot D^{.2} / 127 \cdot 2 \cdot (D_w - D_l) / R_w]$						
Vsd	= DESIGN SETTLING VELOCITY (RECOMMENDED < 10)	IN/MIN	N/A	N/A			
Arb	= REQUIRED AREA OF BOOT $[(W_w / D_w) / (5 \cdot V_s)]$	FT2	N/A	N/A			
Aa	= AVAIL BOOT CSA	FT2	N/A	N/A			
	CHECK BOOT SIZE	-----	N/A	N/A			
PARTICLE DYNAMICS FLOW REGION CALCULATIONS (FOR REFERENCE ONLY)							
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
CR <sub>e</sub> <sup>2</sup>	= $3.355E-9 \cdot D_v^{.3} \cdot (D_l - D_v) / R_v^{.2}$	-----	13820.13	17596.76			
	FLOW REGION (SEE NOTE)	-----	2	2			
Re	= PARTICLE REYNOLDS NUMBER	-----	112.82	134.07			
C	= DRAG COEFFICIENT	-----	1.09	0.98			
U <sub>t</sub>	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	5.77	4.98	1.76	1.52	m/s
V <sub>s</sub>	= SETTLING VELOCITY (CURVE FIT METHOD)	FT/SEC	6.16	5.22	1.88	1.59	m/s
	CURVE FIT % DEVIATION $((V_s - U_t) / U_t) \cdot 100$	-----	7%	5%			
NOTE: GENERALLY THE STOKE'S LAW HOLDS VERY WELL FOR Re. UP TO 1.5, SO FOR $0.3 < Re. < 1.5$ , CALCULATIONS USE THE SMALLER U <sub>t</sub> CALCULATED FROM STOKE'S LAW AND INTERMEDIATE LAW REGIONS.							
1. STOKE'S LAW REGION, $Re \leq 0.3$							
Re	= PARTICLE REYNOLDS NUMBER	-----	575.84	733.20			
C	= DRAG COEFFICIENT $(= 24 / Re)$	-----	0.04	0.03			
U <sub>t</sub>	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	29.47	27.22	8.98	8.30	m/s
	= $2.862855e-8 \cdot D^{.2} \cdot (D_l - D_v) / R_v$						
	CHECK FLOW REGION BASED ON Re		NO GOOD	NO GOOD			
2. INTERMEDIATE LAW REGION, $0.3 < Re \leq 1000$							
Re	= PARTICLE REYNOLDS NUMBER	-----	112.82	134.07			
C	= DRAG COEFFICIENT $(= 18.5 / Re^{.6})$	-----	1.09	0.98			
U <sub>t</sub>	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	5.77	4.98	1.76	1.52	m/s
	= $(1.40726E-4 \cdot D^{.2} \cdot (D_l - D_v) / (D_v \cdot C))^{.5}$						
	CHECK FLOW REGION BASED ON Re		OK	OK			
3. NEWTON'S LAW REGION, $1000 \leq Re < 200000$							
C	= DRAG COEFFICIENT $(= 0.44 \text{ CONSTANT})$	-----	0.44	0.44			
Re	= PARTICLE REYNOLDS NUMBER	-----	177.23	199.98			
U <sub>t</sub>	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	9.07	7.42	2.76	2.26	m/s
	= $1.787587E-2 \cdot (D^{.2} \cdot (D_l - D_v) / D_v)^{.5}$						
	CHECK FLOW REGION BASED ON Re		NO GOOD	NO GOOD			
MIST PAD SIZING (FOR REFERENCE ONLY)							
K	= MIST PAD SIZING FACTOR		0.30	0.30			
U	= VELOCITY THROUGH PAD = $K \cdot ((D_l - D_v) / D_v)^{.5}$	FT/SEC	6.80	5.57	2.07	1.70	m/s
A <sub>req</sub>	= AREA REQUIRED	FT2	6.95	88.87	0.65	8.26	m2
D <sub>req</sub>	= DIAMETER REQUIRED	FT	2.97	10.64	0.91	3.24	m

CLIENT NAME: GASSNOVA  
 PROJECT NAME: CO2 KARSTO  
 BECHTEL JOB NO. 25474

VESSEL SIZING v 1.3 26 February 2008		EQUIP NO	MV-203	MV-104	MV-203	MV-104	
EQUIPMENT NAME		CO2 Compressor Suction Drum	CO2 Compressor 1st Interstage Knockout Drum	CO2 Compressor Suction Drum SI UNITS	1st Stage Drum SI UNITS		SI UNITS
CASE							
<b>INPUT PARAMETERS</b>							
OPERATING PRESSURE	PSIA	26.0	77.5	179.3	534.6		kPaa
OPERATING TEMPERATURE	F	119.7	78.6	48.7	25.9		°C
Wv = VAPOR RATE	LB/HR	328,778	320,453	149131.4	145355.1		kg/h
Dv = VAPOR DENSITY	LB/FT3	0.178	0.606	2.858	9.711		kg/m3
Rv = VAPOR VISCOSITY	CP	0.016	0.015	1.61454E-05	0.00001528		Pa.s
WI = HC LIQUID RATE	LB/HR	190,219	8,325	86281.8	3776.3		kg/h
DI = HC LIQUID DENSITY	LB/FT3	61.674	61.674	988.2	988.2		kg/m3
RI = HC LIQUID VISCOSITY	CP	0.548	0.548	0.000548	0.000548		Pa.s
Ww = WATER RATE	LB/HR	-	-	0	0		kg/h
Dw = WATER DENSITY	LB/FT3	-	-	0	0		kg/m3
Rw = WATER VISCOSITY	CP	-	-	0	0		Pa.s
<b>VESSEL DIMENSIONS</b>							
ORIENTATION (1 - VERTICAL, 2 - HORIZONTAL)			1	1			
<b>DRUM SIZE</b>							
D = INSIDE DIAMETER	FT	13.00	9.00	3.9624	2.7432		m
L = LENGTH (TANG-TANG)	FT	19.50	13.50	5.9436	4.1148		m
Ln = LENGTH (NOZ-NOZ)	FT	19.50	13.50	5.9436	4.1148		m
La = AVAIL. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A				
HLL FROM BOTTOM TANG (FOR HC)	FT	16.50	10.50	5.0292	3.2004		m
NLL FROM BOTTOM TANG (FOR HC)	FT	8.50	5.50	2.5908	1.6764		m
LLL FROM BOTTOM TANG (FOR HC)	FT	0.50	0.50	0.1524	0.1524		m
<b>WATER BOOT SIZE</b>							
Db = INSIDE DIAMETER	FT	N/A	N/A				m
Lb = LENGTH (TANG-TANG)	FT	N/A	N/A				m
HLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A				m
NLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A				m
LLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A				m
LIQUID RESIDENCE TIME TARGET	MIN	6.0	6.0				
<b>OPTIONS</b>							
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
D = DROPLET/PARTICLE SIZE FOR SEPARATION	MICRONS	500.00	500.00				
****BASED ON PARTICLE SIZE SEPARATION (check for HC liq/water)****							
D = DROPLET SIZE FOR SEPARATION	MICRONS	127.00	127.00				
Vsd = DESIGN SETTLING VELOCITY LIMIT	IN/MIN	10.0	10.0	0.004233333	0.004233333		m/s
<b>WATER BOOT SIZE CHECK</b>							
D = DROPLET SIZE FOR SEPARATION	MICRONS	127.00	127.00				
Vsd = DESIGN SETTLING VELOCITY LIMIT	IN/MIN	10.0	10.0	0.004233333	0.004233333		m/s
<b>MIST PAD</b>							
K = MIST PAD SIZING FACTOR		0.30	0.30				
<b>RESIDENCE TIME AND LIQUID DOWNWARD VELOCITY CHECK</b>							
VESSEL SURGE VOLUME FROM HLL-LLL, incl. head for horizontal	GALLONS	15886.505	4758.901	60.137	18.014		m3
<b>FOR VERTICAL DRUM</b>							
HC RESIDENCE TIME HLL-NLL	MIN	20.7	141.4				
HC RESIDENCE TIME NLL-LLL	MIN	20.7	141.4				
TOTAL HC RESIDENCE TIME (HLL-LLL)	MIN	41.3	282.8				
LIQUID DOWNWARD VELOCITY	FT/MIN	0.4	0.0				
LIQ FILL-UP FROM HLL TO TOP, incl. top head	MIN	13.3	127.2				
<b>FOR HORIZONTAL DRUM</b>							
Hh = RISE OF HLL	FT	N/A	N/A				
Ah = LIQ FLOW (SEGMENT) AREA @ HLL	FT2	N/A	N/A				
HI = RISE OF LLL	FT	N/A	N/A				
AI = LIQUID FLOW (SEGMENT) AREA @ LLL	FT2	N/A	N/A				
NET LIQUID CSA (HLL-LLL)	FT2	N/A	N/A				
HC RESIDENCE TIME (HLL-LLL), incl. head	MIN	N/A	N/A				
LIQ FILL-UP FROM HLL TO TOP, incl. head	MIN	N/A	N/A				
<b>FOR WATER BOOT</b>							
WATER RESIDENCE TIME (HLL-LLL)	MIN	N/A	N/A				
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
D = DROPLET/PARTICLE SIZE FOR SEPARATION	MICRONS	500.00	500.00				
CR <sub>e</sub> <sup>2</sup> = 3.355E-9*Dv <sup>3</sup> *(DI-Dv)/Rv <sup>2</sup>	-----	17646.85	66479.65				
C = DRAG COEFFICIENT (CURVE FIT DATA)	-----	0.89	0.64				
Vs = SETTLING VELOCITY	FT/SEC	5.23	3.33	1.592899518	1.01411618		m/s
= 0.01188*(D/C)*0.5*(DI/Dv-1) <sup>0.5</sup>							
L / D = LENGTH (NOZ-NOZ) TO DIAMETER RATIO	-----	1.00	1.00				
Va = ALLOW VELOCITY = 85% * (L/D) * Vs	FT/SEC	4.44	2.83	1.35396459	0.86199876		m/s
Kv = Va / (DI/DV-1) <sup>0.5</sup> (EQUIVALENT)	FT/SEC	0.24	0.28	0.072919708	0.08587379		m/s
Ar = CSA REQ'D FOR VAPOR FLOW = V / Va	FT2	115.263	51.934	10.70828012	4.82480584		m2
IDr = DIAMETER REQ'D FOR VERTICAL DRUM	FT	12.11	8.13	3.692452532	2.47853456		m
Aa = AVAIL VAP PHASE CSA @ HLL FOR HORIZ	FT2	N/A	N/A				
VESSEL SIZE CHECK	-----	OK	OK				

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 BECHTEL JOB NO. 25474

VESSEL SIZING v 1.3 26 February 2008		EQUIP NO	MV-203	MV-104	MV-203	MV-104	
EQUIPMENT NAME			CO2 Compressor Suction Drum	CO2 Compressor 1st Interstage Knockout Drum	CO2 Compressor Suction Drum SI UNITS	1st Stage Drum SI UNITS	SI UNITS
CASE							
****BASED ON PARTICLE SIZE SEPARATION (check for HC liq/water)****							
WATER SETTLING WITH LEVEL							
D	= DROPLET SIZE FOR SEPARATION	MICRONS	N/A	N/A			
Vs	= SETTLING VELOCITY	IN/MIN	N/A	N/A			
	= $[.334 \cdot D^{.2} / 127^{.2} \cdot (Dw-Di)/R]$						
Vsd	= DESIGN SETTLING VELOCITY (RECOMMENDED < 10)	IN/MIN	N/A	N/A			
La	= AVAIL. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
WATER SETTLING WITH LEVEL @ LLL							
V	= LIQUID (HC + H2O) HORIZONTAL VELOCITY	FT/MIN	N/A	N/A			
Hl	= LIQUID HEIGHT @ LLL	INCH	N/A	N/A			
Lr	= REQ. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
	= $[V \cdot Hl / Vsd]$						
	CHECK LLL HEIGHT	-----	N/A	N/A			
WATER SETTLING WITH LEVEL @ HLL							
V	= LIQUID (HC + H2O) HORIZONTAL VELOCITY	FT/MIN	N/A	N/A			
Hh	= LIQUID HEIGHT @ HLL	INCH	N/A	N/A			
Lr	= REQ. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
	= $[V \cdot Hh / Vsd]$						
	CHECK HLL HEIGHT	-----	N/A	N/A			
WATER BOOT SIZE CHECK							
	WATER RESIDENCE TIME (HLL-LLL)	MIN	N/A	N/A			
D	= DROPLET SIZE FOR SEPARATION	MICRONS	N/A	N/A			
Vs	= SETTLING VELOCITY	IN/MIN	N/A	N/A			
	= $[.334 \cdot D^{.2} / 127^{.2} \cdot (Dw-Di)/Rw]$						
Vsd	= DESIGN SETTLING VELOCITY (RECOMMENDED < 10)	IN/MIN	N/A	N/A			
Arb	= REQUIRED AREA OF BOOT $[(Ww/Dw)/(5 \cdot Vs)]$	FT2	N/A	N/A			
Aa	= AVAIL BOOT CSA	FT2	N/A	N/A			
	CHECK BOOT SIZE	-----	N/A	N/A			
PARTICLE DYNAMICS FLOW REGION CALCULATIONS (FOR REFERENCE ONLY)							
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
CR <sup>e2</sup>	= $3.355E-9 \cdot Dv \cdot D^{.3} \cdot (Di-Dv)/Rv^{.2}$	-----	17646.85	66479.65			
	FLOW REGION (SEE NOTE)		2	2			
Re	= PARTICLE REYNOLDS NUMBER	-----	134.34	346.46			
C	= DRAG COEFFICIENT	-----	0.98	0.55			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	4.98	3.58	1.52	1.09	m/s
Vs	= SETTLING VELOCITY (CURVE FIT METHOD)	FT/SEC	5.23	3.33	1.59	1.01	m/s
	CURVE FIT % DEVIATION $((Vs-Ut)/Ut) \cdot 100$		5%	-7%			
NOTE: GENERALLY THE STOKE'S LAW HOLDS VERY WELL FOR Re. UP TO 1.5, SO FOR $0.3 < Re < 1.5$ , CALCULATIONS USE THE SMALLER UI CALCULATED FROM STOKE'S LAW AND INTERMEDIATE LAW REGIONS.							
1. STOKE'S LAW REGION, $Re < 0.3$							
Re	= PARTICLE REYNOLDS NUMBER	-----	735.29	2769.99			
C	= DRAG COEFFICIENT $(=24/Re)$	-----	0.03	0.01			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	27.26	28.60	8.31	8.72	m/s
	= $2.862855E-8 \cdot D^{.2} \cdot (Di-Dv)/Rv$						
	CHECK FLOW REGION BASED ON Re		NO GOOD	NO GOOD			
2. INTERMEDIATE LAW REGION, $0.3 < Re < 1000$							
Re	= PARTICLE REYNOLDS NUMBER	-----	134.34	346.46			
C	= DRAG COEFFICIENT $(=18.5/Re^{.6})$	-----	0.98	0.55			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	4.98	3.58	1.52	1.09	m/s
	= $(1.40726E-4 \cdot D^{.2} \cdot (Di-Dv)/(Dv \cdot C))^{.5}$						
	CHECK FLOW REGION BASED ON Re		OK	OK			
3. NEWTON'S LAW REGION, $1000 < Re < 200000$							
C	= DRAG COEFFICIENT $(=0.44 \text{ CONSTANT})$	-----	0.44	0.44			
Re	= PARTICLE REYNOLDS NUMBER	-----	200.27	388.70			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	7.42	4.01	2.26	1.22	m/s
	= $1.787587E-2 \cdot D^{.2} \cdot (Di-Dv)/Dv^{.5}$						
	CHECK FLOW REGION BASED ON Re		NO GOOD	NO GOOD			
MIST PAD SIZING (FOR REFERENCE ONLY)							
K	= MIST PAD SIZING FACTOR		0.30	0.30			
U	= VELOCITY THROUGH PAD = $K \cdot ((Di-Dv)/Dv)^{.5}$	FT/SEC	5.57	3.01	1.70	0.92	m/s
Areq	= AREA REQUIRED	FT2	91.92	48.77	8.54	4.53	m2
Dreq	= DIAMETER REQUIRED	FT	10.82	7.88	3.30	2.40	m

CLIENT NAME: GASSNOVA  
 PROJECT NAME: CO2 KARSTO  
 BECHTEL JOB NO. 25474

VESSEL SIZING v 1.3 26 February 2008		EQUIP NO	MV-105	MV-106	MV-105	MV-106	
EQUIPMENT NAME		CO2 Compressor 2nd Interstage Knockout Drum	CO2 Surge Drum	2nd Interstage Drum SI UNITS	CO2 Surge Drum SI UNITS	SI UNITS	
CASE							
<b>INPUT PARAMETERS</b>							
OPERATING PRESSURE	PSIA	325.1	1348.3	2241.81	9296.22	kPaa	
OPERATING TEMPERATURE	F	78.7	82.4	25.92	28	°C	
Wv = VAPOR RATE	LB/HR	309,021	15,451	140169.7	7008.485	kg/h	
Dv = VAPOR DENSITY	LB/FT3	2.846	7.719	45.5945	123.68	kg/m3	
Rv = VAPOR VISCOSITY	CP	0.016	0.024	1.59403E-05	0.000024	Pa.s	
Wl = HC LIQUID RATE	LB/HR	839	309,021	380.6	140169.7	kg/h	
DI = HC LIQUID DENSITY	LB/FT3	62.286	45.100	998	722.632	kg/m3	
RI = HC LIQUID VISCOSITY	CP	1.000	0.061	0.001	6.0953E-05	Pa.s	
Ww = WATER RATE	LB/HR	-	-	0	0	kg/h	
Dw = WATER DENSITY	LB/FT3	-	-	0	0	kg/m3	
Rw = WATER VISCOSITY	CP	-	-	0	0	Pa.s	
<b>VESSEL DIMENSIONS</b>							
ORIENTATION (1 - VERTICAL, 2 - HORIZONTAL)		1	1				
<b>DRUM SIZE</b>							
D = INSIDE DIAMETER	FT	6.00	7.00	1.8288	2.1336	m	
L = LENGTH (TANG-TANG)	FT	9.00	21.00	2.7432	6.4008	m	
Ln = LENGTH (NOZ-NOZ)	FT	9.00	21.00	2.7432	6.4008	m	
La = AVAIL. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A				
HLL FROM BOTTOM TANG (FOR HC)	FT	6.00	18.00	1.8288	5.4864	m	
NLL FROM BOTTOM TANG (FOR HC)	FT	3.25	9.25	0.9906	2.8194	m	
LLL FROM BOTTOM TANG (FOR HC)	FT	0.50	0.50	0.1524	0.1524	m	
<b>WATER BOOT SIZE</b>							
Db = INSIDE DIAMETER	FT	N/A	N/A			m	
Lb = LENGTH (TANG-TANG)	FT	N/A	N/A			m	
HLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A			m	
NLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A			m	
LLL FROM BOTTOM TANG (FOR WTR)	FT	N/A	N/A			m	
LIQUID RESIDENCE TIME TARGET	MIN	6.0	6.0				
<b>OPTIONS</b>							
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
D = DROPLET/PARTICLE SIZE FOR SEPARATION	MICRONS	500.00	500.00				
****BASED ON PARTICLE SIZE SEPARATION (check for HC liq/water)****							
D = DROPLET SIZE FOR SEPARATION	MICRONS	127.00	127.00				
Vsd = DESIGN SETTLING VELOCITY LIMIT	IN/MIN	10.0	10.0	0.004233333	0.004233333	m/s	
<b>WATER BOOT SIZE CHECK</b>							
D = DROPLET SIZE FOR SEPARATION	MICRONS	127.00	127.00				
Vsd = DESIGN SETTLING VELOCITY LIMIT	IN/MIN	10.0	10.0	0.004233333	0.004233333	m/s	
<b>MIST PAD</b>							
K = MIST PAD SIZING FACTOR		0.30	0.30				
<b>RESIDENCE TIME AND LIQUID DOWNWARD VELOCITY CHECK</b>							
VESSEL SURGE VOLUME FROM HLL-LLL, incl. head for horizontal	GALLONS	1163.287	5037.973	4.404	19.071	m3	
<b>FOR VERTICAL DRUM</b>							
HC RESIDENCE TIME HLL-NLL	MIN	346.3	2.9				
HC RESIDENCE TIME NLL-LLL	MIN	346.3	2.9				
TOTAL HC RESIDENCE TIME (HLL-LLL)	MIN	692.6	5.9				
LIQUID DOWNWARD VELOCITY	FT/MIN	0.0	3.0				
LIQ FILL-UP FROM HLL TO TOP, incl. top head	MIN	503.7	1.4				
<b>FOR HORIZONTAL DRUM</b>							
Hh = RISE OF HLL	FT	N/A	N/A				
Ah = LIQ FLOW (SEGMENT) AREA @ HLL	FT2	N/A	N/A				
HI = RISE OF LLL	FT	N/A	N/A				
AI = LIQUID FLOW (SEGMENT) AREA @ LLL	FT2	N/A	N/A				
NET LIQUID CSA (HLL-LLL)	FT2	N/A	N/A				
HC RESIDENCE TIME (HLL-LLL), incl. head	MIN	N/A	N/A				
LIQ FILL-UP FROM HLL TO TOP, incl. head	MIN	N/A	N/A				
<b>FOR WATER BOOT</b>							
WATER RESIDENCE TIME (HLL-LLL)	MIN	N/A	N/A				
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
D = DROPLET/PARTICLE SIZE FOR SEPARATION	MICRONS	500.00	500.00				
CR <sub>e</sub> <sup>2</sup> = 3.355E-9*D <sup>3</sup> *D <sup>3</sup> *(DI-DV)/R <sup>2</sup>	-----	279162.37	210079.91				
C = DRAG COEFFICIENT (CURVE FIT DATA)	-----	0.50	0.52				
Vs = SETTLING VELOCITY	FT/SEC	1.72	0.81	0.52341397	0.24678818	m/s	
= 0.01186*(D/C) <sup>0.5</sup> *(DI/DV-1) <sup>0.5</sup>							
L / D = LENGTH (NOZ-NOZ) TO DIAMETER RATIO	-----	1.00	1.00				
Va = ALLOW VELOCITY = 85% * (L/D) * Vs	FT/SEC	1.46	0.69	0.444901874	0.20976995	m/s	
Kv = Va / (DI/DV-1) <sup>0.5</sup> (EQUIVALENT)	FT/SEC	0.32	0.31	0.097344074	0.09532285	m/s	
Ar = CSA REQ'D FOR VAPOR FLOW = V / Va	FT2	20.667	0.808	1.919984004	0.07505879	m2	
IDr = DIAMETER REQ'D FOR VERTICAL DRUM	FT	5.13	1.01	1.563521525	0.30914045	m	
Aa = AVAIL VAP PHASE CSA @ HLL FOR HORIZ	FT2	N/A	N/A				
VESSEL SIZE CHECK	-----	OK	OK				

CLIENT NAME: GASSNOVA  
 PROJECT NAME: CO2 KARSTO  
 BECHTEL JOB NO. 25474

VESSEL SIZING v 1.3 26 February 2008		EQUIP NO	MV-105	MV-106	MV-105	MV-106	
EQUIPMENT NAME			CO2 Compressor 2nd Interstage Knockout Drum	CO2 Surge Drum	2nd Interstage Drum SI UNITS	CO2 Surge Drum SI UNITS	SI UNITS
CASE							
****BASED ON PARTICLE SIZE SEPARATION (check for HC liq/water)****							
WATER SETTLING WITH LEVEL							
D	= DROPLET SIZE FOR SEPARATION	MICRONS	N/A	N/A			
Vs	= SETTLING VELOCITY	IN/MIN	N/A	N/A			
	= $[.334 \cdot D^{.2} / 127 \cdot 2 \cdot (D_w - D_i) / R_i]$						
Vsd	= DESIGN SETTLING VELOCITY (RECOMMENDED < 10)	IN/MIN	N/A	N/A			
La	= AVAIL. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
WATER SETTLING WITH LEVEL @ LLL							
V	= LIQUID (HC + H2O) HORIZONTAL VELOCITY	FT/MIN	N/A	N/A			
Hl	= LIQUID HEIGHT @ LLL	INCH	N/A	N/A			
Lr	= REQ. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
	= $[V \cdot H_l / V_{sd}]$						
	CHECK LLL HEIGHT	-----	N/A	N/A			
WATER SETTLING WITH LEVEL @ HLL							
V	= LIQUID (HC + H2O) HORIZONTAL VELOCITY	FT/MIN	N/A	N/A			
Hh	= LIQUID HEIGHT @ HLL	INCH	N/A	N/A			
Lr	= REQ. LENGTH FOR WATER DROPLET SETTLING	FT	N/A	N/A			
	= $[V \cdot H_h / V_{sd}]$						
	CHECK HLL HEIGHT	-----	N/A	N/A			
WATER BOOT SIZE CHECK							
	WATER RESIDENCE TIME (HLL-LLL)	MIN	N/A	N/A			
D	= DROPLET SIZE FOR SEPARATION	MICRONS	N/A	N/A			
Vs	= SETTLING VELOCITY	IN/MIN	N/A	N/A			
	= $[.334 \cdot D^{.2} / 127 \cdot 2 \cdot (D_w - D_i) / R_w]$						
Vsd	= DESIGN SETTLING VELOCITY (RECOMMENDED < 10)	IN/MIN	N/A	N/A			
Arb	= REQUIRED AREA OF BOOT $[(W_w / D_w) / (5 \cdot V_s)]$	FT2	N/A	N/A			
Aa	= AVAIL BOOT CSA	FT2	N/A	N/A			
	CHECK BOOT SIZE	-----	N/A	N/A			
PARTICLE DYNAMICS FLOW REGION CALCULATIONS (FOR REFERENCE ONLY)							
****BASED ON PARTICLE SIZE SEPARATION (check for HC vap/liq)****							
CR <sup>2</sup>	= $3.355E-9 \cdot D_v^{.3} \cdot (D_i - D_v) / R_v^{.2}$	-----	279162.37	210079.91			
	FLOW REGION (SEE NOTE)		2	2			
Re	= PARTICLE REYNOLDS NUMBER	-----	965.55	788.10			
C	= DRAG COEFFICIENT	-----	0.30	0.34			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	2.22	1.00	0.68	0.31	m/s
Vs	= SETTLING VELOCITY (CURVE FIT METHOD)	FT/SEC	1.72	0.81	0.52	0.25	m/s
	CURVE FIT % DEVIATION $((V_s - U_t) / U_t) \cdot 100$		-22%	-19%			
NOTE: GENERALLY THE STOKE'S LAW HOLDS VERY WELL FOR Re. UP TO 1.5. SO FOR $0.3 < Re. < 1.5$ , CALCULATIONS USE THE SMALLER U_t CALCULATED FROM STOKE'S LAW AND INTERMEDIATE LAW REGIONS.							
1. STOKE'S LAW REGION, $Re \leq 0.3$							
Re	= PARTICLE REYNOLDS NUMBER	-----	11631.77	8753.33			
C	= DRAG COEFFICIENT (=24/Re)	-----	0.00	0.00			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	26.69	11.15	8.13	3.40	m/s
	= $2.862855e-8 \cdot D^{.2} \cdot (D_i - D_v) / R_v$						
	CHECK FLOW REGION BASED ON Re		NO GOOD	NO GOOD			
2. INTERMEDIATE LAW REGION, $0.3 < Re \leq 1000$							
Re	= PARTICLE REYNOLDS NUMBER	-----	965.55	788.10			
C	= DRAG COEFFICIENT (=18.5/Re <sup>0.6</sup> )	-----	0.30	0.34			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	2.22	1.00	0.68	0.31	m/s
	= $(1.40726E-4 \cdot D^{.2} \cdot (D_i - D_v) / (D_v \cdot C))^{.5}$						
	CHECK FLOW REGION BASED ON Re		OK	OK			
3. NEWTON'S LAW REGION, $1000 \leq Re < 200000$							
C	= DRAG COEFFICIENT (~0.44 CONSTANT)	-----	0.44	0.44			
Re	= PARTICLE REYNOLDS NUMBER	-----	796.53	690.98			
Ut	= TERMINAL VELOCITY BY FLOW REGION	FT/SEC	1.83	0.88	0.56	0.27	m/s
	= $1.787587E-2 \cdot (D^{.2} \cdot (D_i - D_v) / D_v)^{.5}$						
	CHECK FLOW REGION BASED ON Re		NO GOOD	NO GOOD			
MIST PAD SIZING (FOR REFERENCE ONLY)							
K	= MIST PAD SIZING FACTOR		0.30	0.30			
U	= VELOCITY THROUGH PAD = $K \cdot ((D_i - D_v) / D_v)^{.5}$	FT/SEC	1.37	0.66	0.42	0.20	m/s
Areq	= AREA REQUIRED	FT2	22.00	0.84	2.04	0.08	m2
Dreq	= DIAMETER REQUIRED	FT	5.29	1.04	1.61	0.32	m