CO2 Liquefaction Plant #500

Contact
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1. Executive Summary

1.1 Plant Capacity

- 300 tons per day

1.2 Plant History

- Built in 1986.

1.3 Specifications of Raw and Product CO2 and

- Crude CO2 purity: 94.7 mol%.
- Product liquid CO2 at 1549 kpaA and -28.9 °C, purity 99.99 mol%.

1.4 Consumption Data

- Water 3,343,420 m3/year
- Energy 9,369,600 KWh
- Ammonia 4,615 Kg (7,500 L)

2. Process Description

The CO2 process and compression system is designed to purify and condense raw (crude) CO2 gas. The crude CO2 feed stock enters the system at a pressure of 250 kPaA and ambient temperature with a 94.7 mole percent CO2 content. The crude CO2 gas is processed to yield a liquid product at 1530 - 1700 kPaG pressure and -23° to -28° C temperature, with a CO2 purity of 99.99 mole percent.

The crude CO2 undergoes a front-end cooling process in order to condense and eliminate enough entrained water from the gas stream to avoid condensation on the compressor inter-stage. The crude CO2 stream is cooled from ambient temperature down to 6ºC in the plant inlet chiller, where the condensed part of the water in the gas will drop out.

From the inlet chiller CO2 gas flows into the inlet separator where the free water is removed from the gas stream and discharged to the condensate tank through a constant level control system. At this point enough water was removed from the crude gas stream so that no condensation will occur during the compression process.

From the plant inlet separator, the gas is drawn directly to the suction port of the first stage CO2 compressor. The crude CO2 gas is compressed by a two-stage compressor train and discharged. During the compression stage, lube oil is injected into the compressors to lubricate the bearings and to control the compressor discharge temperature. The oil-gas mixture enters the CO2 compressor primary oil separator where the oil is removed from the crude CO2 and held in the

bottom of the vessel. The crude CO2 vapor passes through a two-step coalescing filter system, which yields approximately 6 - 8 ppm oil carry over. The crude CO2 vapor is then cleaned to 3 ppm maximum oil content by passing through the secondary oil separator before proceeding to the catox reactor skid at 2050 kPaG and 90° C. Good CO2 oil removal is ensured through regular inspection and maintenance of the oil separators. The oil is pumped from the primary oil separator through the CO2 compressor lube oil cooler where cooling water is used to cool the oil from 90ºC to 35°C - 50°C. The oil is then filtered to 10 microns and injected back into the compressors.

The crude CO2 gas exiting the secondary oil separator passes into the reactor system carbon bed where the last traces of oil are absorbed. Just downstream of the carbon bed, pure oxygen gas is added to the crude CO2 gas. The gas mixture then travels through the tube side of the reactor gas/gas heat exchanger into the reactor heater to get pre-heated to a temperature of 370ºC. At certain times, a portion of the crude CO2 stream is bypassed around the reactor gas/gas exchanger, into the reactor heater inlet, for temperature control purposes.

Downstream of the reactor heater the crude CO2 gas enters the reactor catalyst bed where the hydrogen gas and hydrocarbons are converted to CO2 and water vapor. Temperature in the reactor catalyst bed reaches 490ºC. The semi-purified CO2 exits the catalyst bed into the shell side of the reactor gas/gas exchanger where it is cooled to 180 - 220°C by the counter flowing crude CO2 stream. The semi-purified CO2 stream is further cooled to 40°C by cooling water during its pass through the reactor skid trim cooler.

Upon leaving the reactor system, the process CO2 gets cooled initially with cooling water to approximately ambient temperature in the high-pressure aftercooler, and secondly to 6ºC by ammonia in the high-pressure chiller. The temperature reduction process is in order to condense and eliminate 95% or more of the remaining water. After leaving the CO2 chiller, the gas enters the CO2 high-pressure separator where the free water is removed from the gas stream and discharged to the condensate tank through a constant level control system. From the top of the high-pressure separator, the process CO2 gas flows through the CO2 driers to further remove the remaining 3-5% of water.

To ensure an odor free product, the dry process CO2 gas from the driers is passed through a packed bed of activated carbon in the carbon beds. The activated carbon absorbs all possible traces of chlorine, chlorinated organics and aromatics that may be present in the dry process CO2 gas stream. After exiting the carbon bed, the process gas containing inert impurities is cooled in the CO2 bundle of the CO2 reboiler from 6°C to -15°C. Next, it is joined with CO2 vapor from the top of the stripper column and condensed in the tube side of the CO2 condenser. The remaining uncondensed gas from the CO2 condenser is taken to the vent condenser where it is cooled further, to condense as much CO2 as possible.

The condensed impure CO2 from the CO2 condenser along with the condensate from the vent condenser will collect into the reflux vessel. From the reflux vessel the liquid is pumped to the top of the stripper column. Where inert impurities are stripped from the liquid by contacting it

with upward flowing CO2 vapors from the shell side of the reboiler. Heat is provided to the reboiler by passing the CO2 gas from the drier system through one bundle as described above, as well as, by sub cooling liquid ammonia in a second bundle. The sub cooled ammonia will then provide the cooling medium for the CO2 condenser and subcooler.

The CO2 vent condenser uses liquid CO2 from the subcooler as cooling medium. The vaporized CO2 from the vent condenser shell joins with recycle CO2 vapor from the storage tanks before it passes through the tube side of a CO2 gas heater. After warming, a portion of the recycle gas is then used for drier & carbon bed regeneration. The unused (by regeneration) portion of the recycle gas is taken back to the CO2 compressor inter-stage. The gas used to regenerate the driers is recovered by filtering and moisture removal before it is fed into the CO2 compressor inter-stage. The recycle gas used to regenerate the carbon beds is not recovered, but goes directly to vent. Liquid CO2 from the bottom of the reboiler is taken to the subcooler where it is sub cooled by ammonia to -28°C before being discharged to the storage tank(s).

3. Equipment List

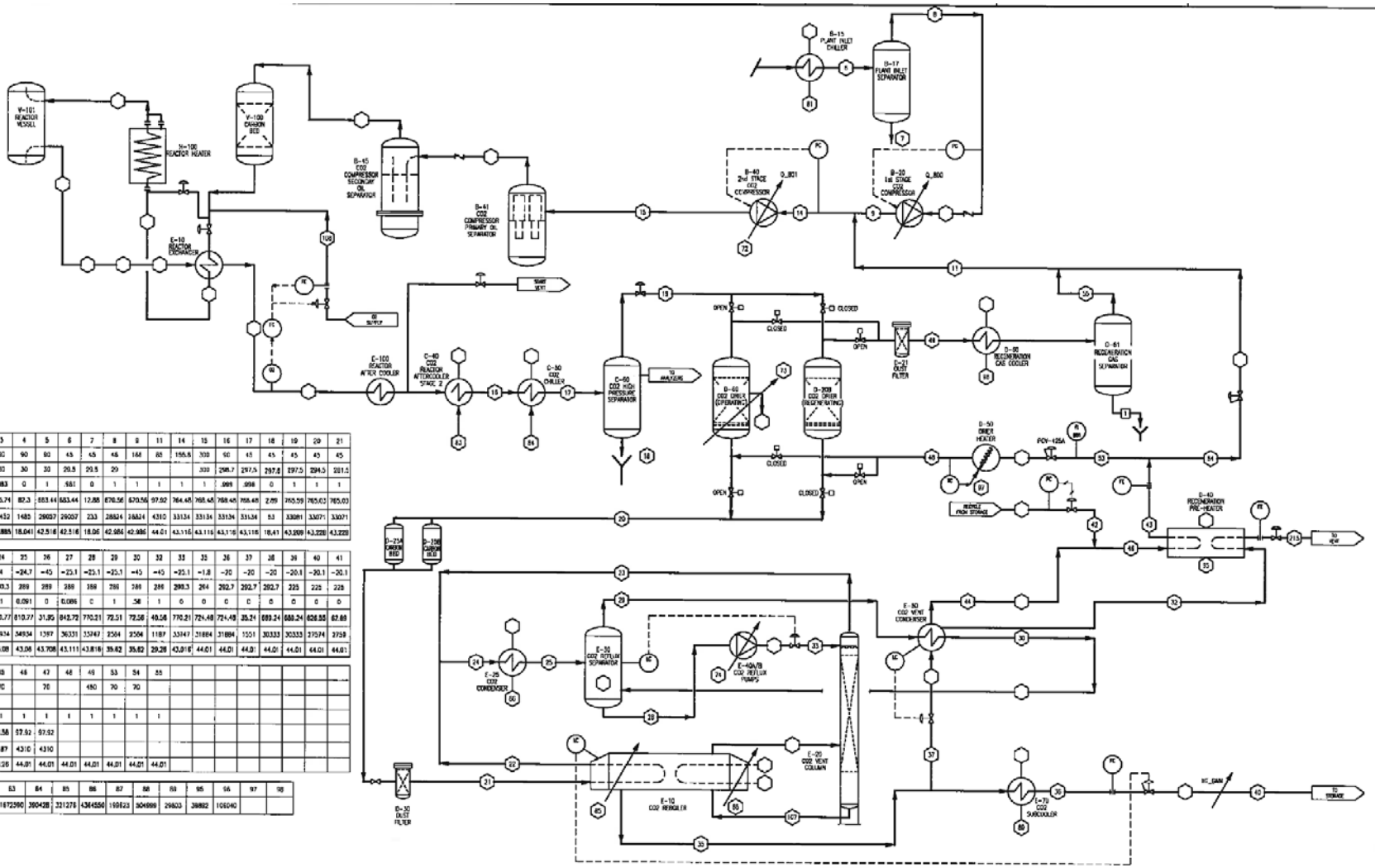
Tag number	Description	Skid	Dimensions	Shipping Weight
A-10	Inlet water separator	Blower	60" ID X 7' H	
A-20 A/B	CO2 Blowers	Blower		5250 lbs
A-30	CO2 Aftercooler	Blower	24" X 144"	4600 lbs
A-40	Aftercooler separator	Blower	42" ID X 7' H	
B-15	Plant inlet chiller	CO2 skid	432 mm = ID x 1829 mm F/F	249 KG
B-17	Plant inlet separator	Process skid A	1067 mm = OD x 1524 mm S/S	962 KG
B-20	1st stage CO2 compressor	CO2 skid		2750 KG
B-30	1st & 2nd stage CO2 compressor motor	CO2 skid		3942 KG
B-40	2nd stage Co2 compressor	CO2 skid		1135 KG
B-41	CO2 compressor primary oil separator	CO2 skid		1635 KG
B-42 A/B	CO2 compressor oil pumps	CO2 skid		68 KG
B-42 A/B motors	CO2 compressor oil pump motors	CO2 skid		82.5 KG
B-43	CO2 compressor oil coolers	CO2 skid	330 = ID x 6096 F/F	1406 KG
B-44 A/B	CO2 compressor lube oil filters	CO2 skid	406 = OD x 710 F/S	260 KG
B-45	CO2 compressor secondary oil separator	CO2 skid	406 = OD x 710 F/S	467 KG

C-40	CO2 compressor aftercooler	Process skid A	483 = ID x 3048 mm F/S	1400 KG
C-50	CO2 chiller	Process skid A	254 mm = ID x 4877 mm F/F	771 KG
C-60	CO2 high pressure separator	CO2 skid	610 mm = OD x 1524 mm S/S	530 KG
D-20 A& B	Carbon dioxide driers	Process skid A	914 = OD x 2438 mm S/S	1360 KG
D-21	Dust filter	CO2 skid	168 mm OD x 1295 mm S/F	129 KG
D-25 A & B	Carbon bed adsorber	Process skid A	914 = OD x 2438 mm S/S	1360 KG
D-30	Dust filter	Process skid A	356 mm x 1372 mm F/S	510 KG
D-40	CO2 gas heater	Process skid B		
D-50	Drier heater	Process skid A		165 KG
D-55	Carbon bed heater	Process skid A		165 KG
D-60	Regeneration gas cooler	Process skid A	203 mm = ID x 2642 mm TL	295 KG
D-61	Regeneration gas cooler separator	CO2 skid	356 mm X 762 mm S/S	123 KG
E-10	CO2 reboiler	Process skid A	361 mm / 584 mm ID x 6095 mm F/F	2137 KG
E-20	CO2 vent column	Alone	508 mm x 9144 mm S/F	3155 KG
E-25	CO2 condenser	Process skid B	584 mm / 1041 mm ID x 9144 mm F/F	1110 KG
E-30	CO2 reflux system	Process skid B		
E-40 A & B	CO2 reflux pumps	Process skid B		
E-40 A & B motors	CO2 reflux pumps motors	Process skid B		38 KG
E-50	CO2 vent condenser	Process skid B	152 mm x 305 mm ID x 3658 F/F	318 KG
E-70	CO2 subcooler	Process skid B	203 mm ID x 6096 mm F/F	585 KG
E-100	Reactor gas / gas exchanger	Catox skid	406 mm OD x 9144 mm T/L	3160 KG
E-101	Reactor aftercooler	Catox skid	406 mm OD x 3048 mm T/L	1295 KG
F-20	1st stage NH3 compressor	NH3 skid		3105 KG
F-25	1st & 2nd stage NH3 compressor motor	NH3 skid		1860 KG
F-30	NH3 compressor interstage cooler	NH3 skid	387mmID x 7315 mm S/S	2675 KG
F-35	NH3 interstage receiver	Process skid A		

F-40	2nd stage NH3 compressor	NH3 skid		1367 KG
F-41	NH3 compressor oil separator	NH3 skid		1650 KG
F-42 A/B	NH3 compressor oil pumps	NH3 skid		68 KG
F-43	NH3 compressor oil cooler	NH3 skid	254 mm id X 6096 mm F/F	912 KG
F-44 A/B	NH3 filters	NH3 skid		
F-50	NH3 condenser	Process skid B		
F-60	NH3 receiver	Process skid B		
F-61 A/B	Liquid NH3 pumps	Process skid B		
H-100	Reactor heater	Catox skid	324 mm OD x 2153 mm S/F	365 KG
V-100	Catox carbon bed	Catox skid	914 mm OD x 1830 mm S/S	1050 KG
V-101	Catox reactor vessel	Catox skid	1067 mm ID x 2286 mm S/S	1680 KG

4. Process Flow Diagram

Phoenix
equipment corporation



STREAM	1	2	3	4	5	6	7	8	9	11	14	15	16	17	18	19	20	21
TEMPERATURE °F	131	274	90	90	90	45	45	45	168	85	155.6	300	90	45	45	45	45	45
PRESSURE PSIA	18	33	30	30	30	29.5	29.5	29				300	298.7	297.5	297.5	297.5	294.5	291.5
VAPOUR FRACTION	1	1	.883	0	1	.981	0	1	1	1	1	1	.998	.998	0	1	1	1
FLOW RATE LB MOLE/Hr	765.74	765.74	765.74	82.3	683.44	683.44	12.88	670.56	670.56	97.92	764.48	765.48	765.48	765.48	2.99	765.59	765.03	765.03
MASS FLOW LB/Hr	30542	30542	30432	1483	29037	29037	233	28804	28804	4310	33134	33134	33134	33134	53	33081	33071	33071
AVERAGE MOLE WT	39.885	39.885	39.885	18.041	42.518	42.518	18.06	42.984	42.984	44.01	43.316	43.316	43.316	43.316	18.41	43.209	43.228	43.228

STREAM	22	23	24	25	26	27	28	29	30	32	33	35	36	37	38	39	40	41
TEMPERATURE °F	5	-13.3	4	-24.7	-45	-23.1	-23.1	-25.1	-45	-45	-25.1	-1.8	-20	-20	-20	-20.1	-20.1	-20.1
PRESSURE PSIA	293.5	293.5	293.5	289	289	288	288	286	286	286	286.5	264	262.7	262.7	262.7	225	225	225
VAPOUR FRACTION	1	1	1	0.091	0	0.086	0	1	.58	1	0	0	0	0	0	0	0	0
FLOW RATE LB MOLE/Hr	765.03	45.74	810.77	810.77	31.95	842.72	770.21	72.51	72.58	48.58	770.21	724.48	724.48	35.24	689.24	689.24	626.55	62.69
MASS FLOW LB/Hr	33071	1863	34934	34934	1397	36331	33247	3504	3504	1189	33247	31884	31884	1551	30333	30333	27574	2759
AVERAGE MOLE WT	43.228	40.7	43.08	43.08	43.708	43.111	43.816	35.62	35.62	29.28	43.016	44.01	44.01	44.01	44.01	44.01	44.01	44.01

STREAM	42	44	45	46	47	48	49	53	54	55
TEMPERATURE °F	-44.5	-36	70		70		450	70	70	
PRESSURE PSIA										
VAPOUR FRACTION	1	1	1	1	1	1	1	1	1	
FLOW RATE LB MOLE/Hr	62.69	35.24	42.56	57.92	57.92					
MASS FLOW LB/Hr	2758	1551	1187	4310	4310					
AVERAGE MOLE WT	44.01	44.01	29.26	44.01	44.01	44.01	44.01	44.01	44.01	44.01

STREAM	80	81	83	84	85	86	87	88	89	95	96	97	98
DUTY BTU/Hr	2895870	529883	1672590	390428	321278	4364550	169823	304999	29803	28882	109040		

NOTE:
TABLE NOT REVISED
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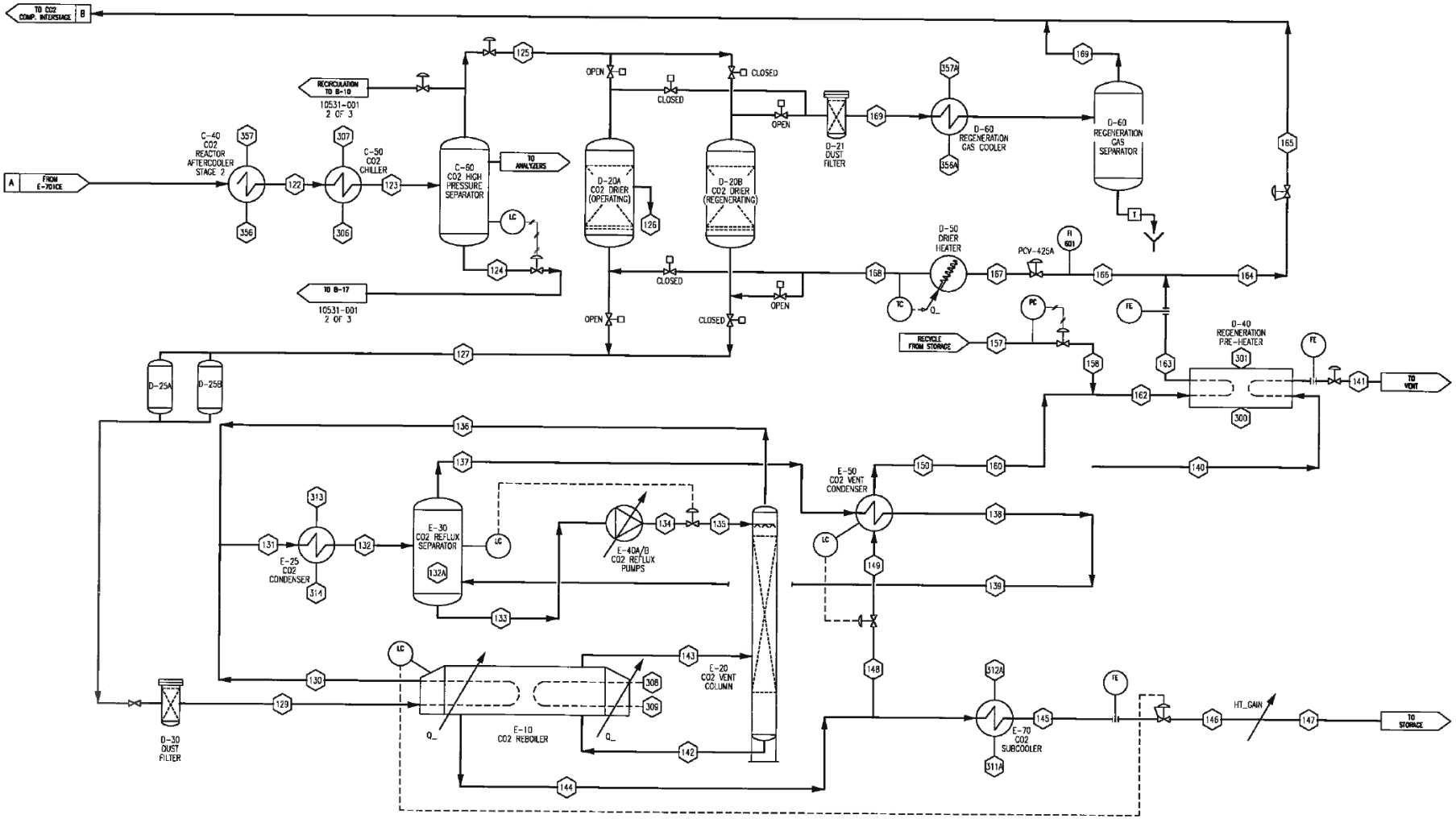
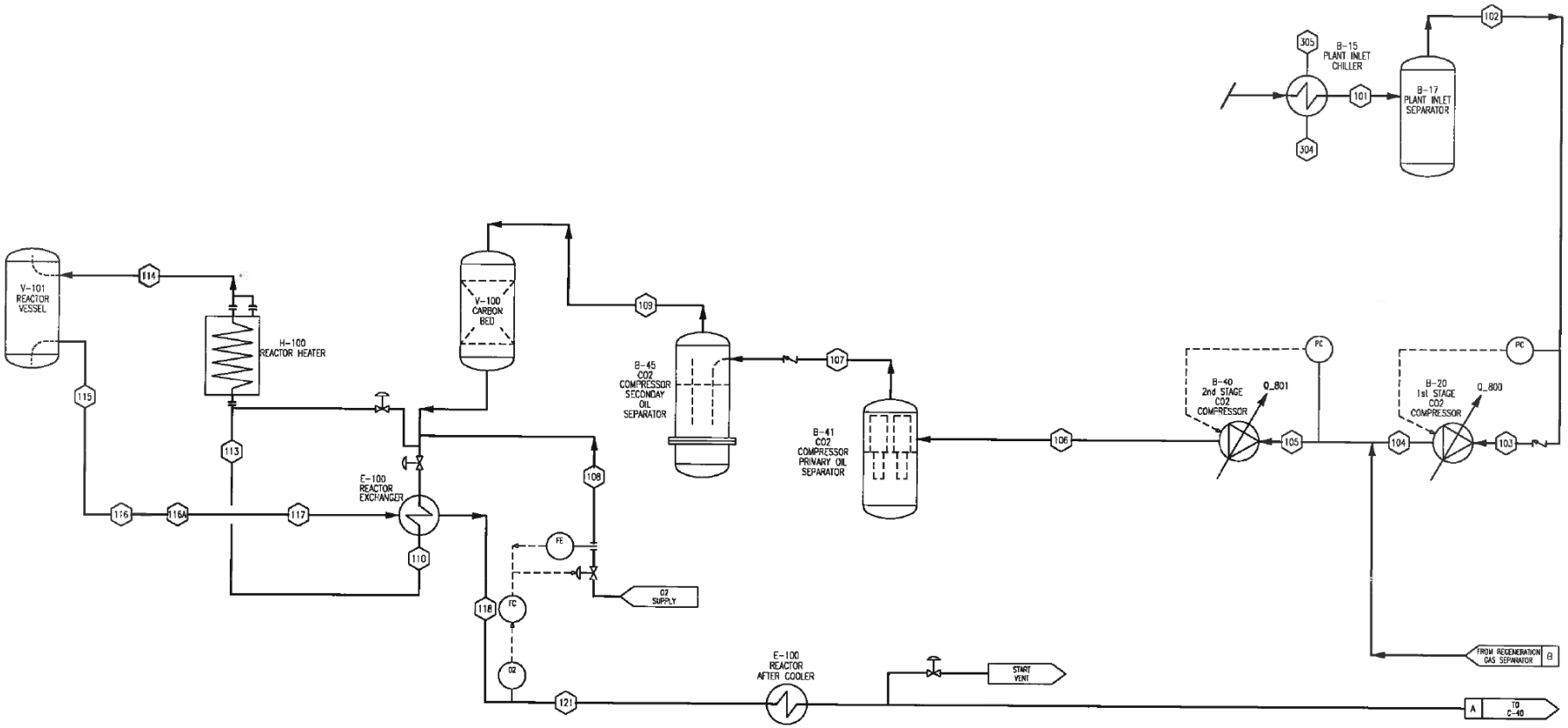

TO CO2 COMP. INTERSTAGE
B
A
FROM E-70/ICE
C-40 CO2 REACTOR AFTERCOOLER STAGE 2
C-50 CO2 CHILLER
C-60 CO2 HIGH PRESSURE SEPARATOR
TO ANALYZERS
RECIRCULATION TO B-10
10531-001 2 OF 3
TO B-17
10531-001 2 OF 3
D-20A CO2 DRIER (OPERATING)
D-20B CO2 DRIER (REGENERATING)
OPEN
CLOSED
D-21 DUST FILTER
D-60 REGENERATION GAS COOLER
D-60 REGENERATION GAS SEPARATOR
D-50 DRIER HEATER
PCV-425A
RECYCLE FROM STORAGE
D-40 REGENERATION PRE-HEATER
TO VENT
D-25A
D-25B
E-25 CO2 CONDENSER
E-30 CO2 REFLUX SEPARATOR
E-40A/B CO2 REFLUX PUMPS
E-50 CO2 VENT CONDENSER
E-10 CO2 REBOILER
E-20 CO2 VENT COLUMN
D-30 DUST FILTER
E-70 CO2 SUBCOOLER
HT_GAIN
TO STORAGE


V-101
REACTOR
VESSEL
H-100
REACTOR HEATER
V-100
CARBON
BED
E-100
REACTOR
EXCHANGER
B-45
CO2
COMPRESSOR
SECONDAY
OIL
SEPARATOR
B-41
CO2
COMPRESSOR
PRIVARY OIL
SEPARATOR
B-40
2nd STAGE
CO2
COMPRESSOR
Q_801
B-20
1st STAGE
CO2
COMPRESSOR
Q_800
B-15
PLANT INLET
CHILLER
B-17
PLANT INLET
SEPARATOR
E-100
REACTOR
AFTER COOLER
C2
SUPPLY
START
VENT
FROM REGENERATION
GAS SEPARATOR
B
A
TO
C-40
PC
FE
TC
O2
101
102
103
104
105
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107
108
109
110
113
114
115
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116A
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305