Cost Efficient Amine Plant Design for Post Combustion CO_2 Capture from Power Plant Flue Gas

A CO_2 Capture Project (CCP) Funded Study -

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Presentation Outline

- *Objective*
- *Study Methodology*
- *Design Basis, Criteria and Considerations*
- *Results*
  - *Reference CO_2 Capture Plant*
  - *Cost Reduction Ideas & Trade-off Evaluations*
  - *Development of an Alternative Low-Cost Amine CO_2 Plant Design [to be discussed in P. Hurst's talk]*
  - *Integrated NGCC/Low-Cost Amine Plant Design [to be discussed in P. Hurst's talk]*
- *Conclusions [to be discussed in P. Hurst's talk]*

Study Objective

- Perform brainstorming exercise and value-engineering analysis to identify design changes needed to reduce the capital and operating cost of an amine based CO_2 capture plant by 50-to-70%

Study Methodology

Phase 1

- Develop a Reference Plant design and cost estimate
- Conduct brainstorming exercise to generate cost reduction ideas
- Perform qualitative screening analysis to select and prioritize ideas for quantitative trade-off analysis
- Perform quantitative trade-off (plant optimization) analysis to determine feasibilities and final design change selection

Phase II

- Develop a Low-Cost stand-alone amine capture plant design and cost estimate

Phase III

- Develop an integrated NGCC/Low-Cost amine plant design and cost estimate

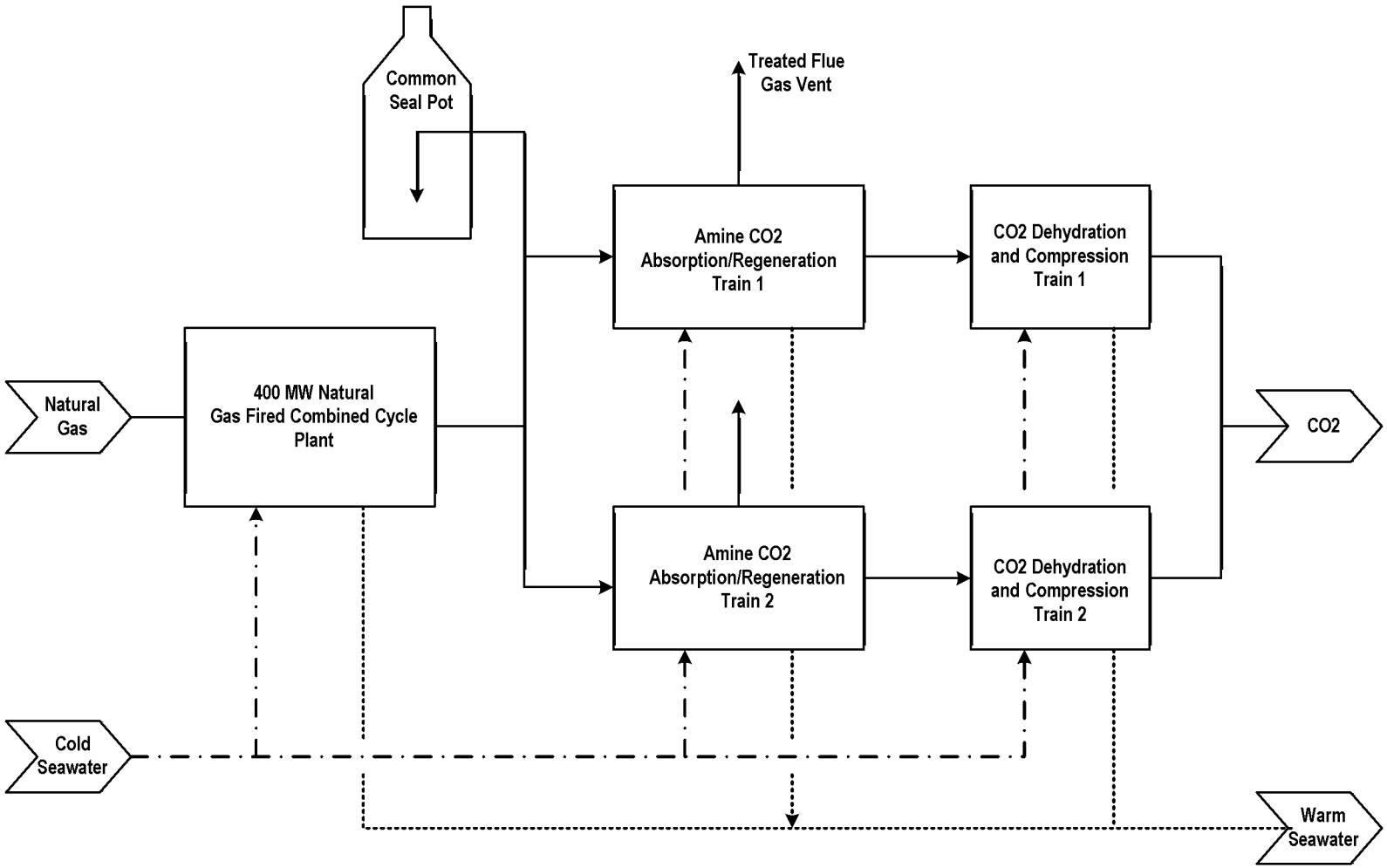
Design Basis, Criteria and Considerations (1)

- Norwegian coastal site w/seawater for cooling (11 ^{o}C / 22 ^{o}C)
- Amine plant accepts the flue gas feed directly from the HRSG outlet of a 400 MW NGCC plant
- 85+ % CO_2 removal
- CO_2 product specifications
  - 220 barg/60 ^{o}C B/L
  - 50 ppmv maximum moisture
- 30 wt% MEA solvent based process
- The Reference Plant is be designed to meet API and refining specifications

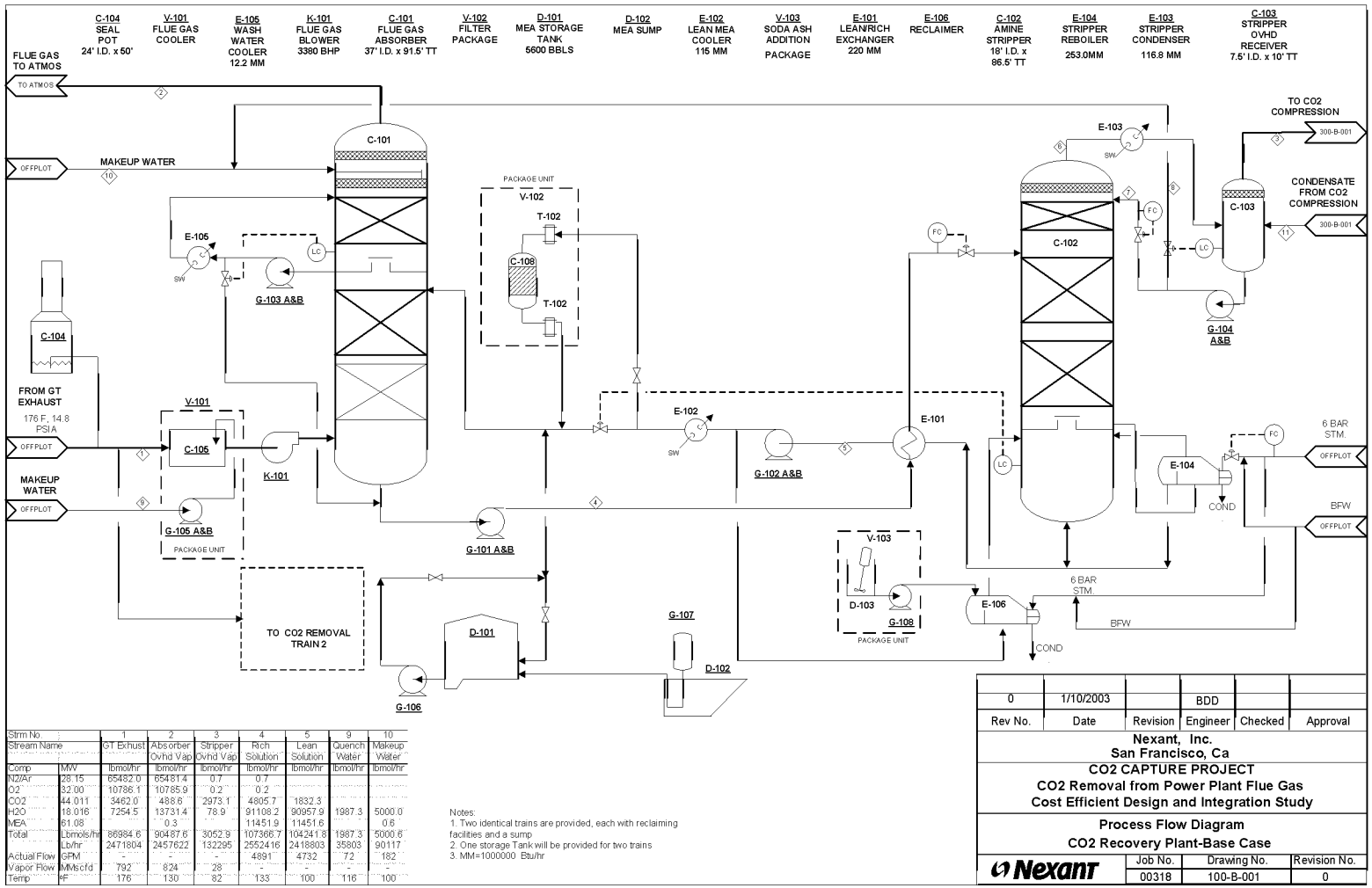
Design Basis, Criteria and Considerations (2)

- The Low-Cost capture plant is be designed
  - With less-stringent design specifications
  - For non-critical service
  - Using commercially-ready technologies
- The Integrated plant is to be design as a Greenfield plant; considered as a longer-term (over 10 years) option with more extensive equipment development if needed
- All designs are to be completed with detailed H&M and utility balances, and all major equipment sized
- Capital cost is to based on major equipment factored cost estimate with equipment costs either provided by the vendors or developed using ICARUS and/or in-house historical data

Amine CO_2 Plant as 'Added-On' to a 400 MW NGCC Plant – Overall System Configuration



Amine (30% MEA) CO_2 Removal – Reference Plant



Strm No.		1	2	3	4	5	9	10
Stream Name		GT Exhust	Absorber Ovhd Vap	Stripper Ovhd Vap	Rich Solution	Lean Solution	Quench Water	Makeup Water
Comp	MW	lbmol/hr	lbmol/hr	lbmol/hr	lbmol/hr	lbmol/hr	lbmol/hr	lbmol/hr
N2/Ar	28.15	65482.0	65481.4	0.7	0.7	-	-	-
O2	32.00	10786.1	10785.9	0.2	0.2	-	-	-
CO2	44.011	3462.0	488.6	2973.1	4805.7	1832.3	-	-
H2O	18.016	7254.5	13731.4	78.9	91108.2	90957.9	1987.3	5000.0
MEA	61.08	-	0.3	-	11451.9	11451.6	-	0.6
Total	Lbmols/hr	86984.6	90487.6	3052.9	107366.7	104241.8	1987.3	5000.6
	Lb/hr	2471804	2457622	132295	2552416	2418803	35803	90117
Actual Flow	GPM	-	-	-	4891	4732	72	182
Vapor Flow	MMscfd	792	824	28	-	-	-	-
Temp	°F	176	130	82	133	100	116	100

Notes:
1. Two identical trains are provided, each with reclaiming facilities and a sump
2. One storage Tank will be provided for two trains
3. MM=1000000 Btu/hr

Rev No.	Date	Revision	Engineer	Checked	Approval
0	1/10/2003		BDD		

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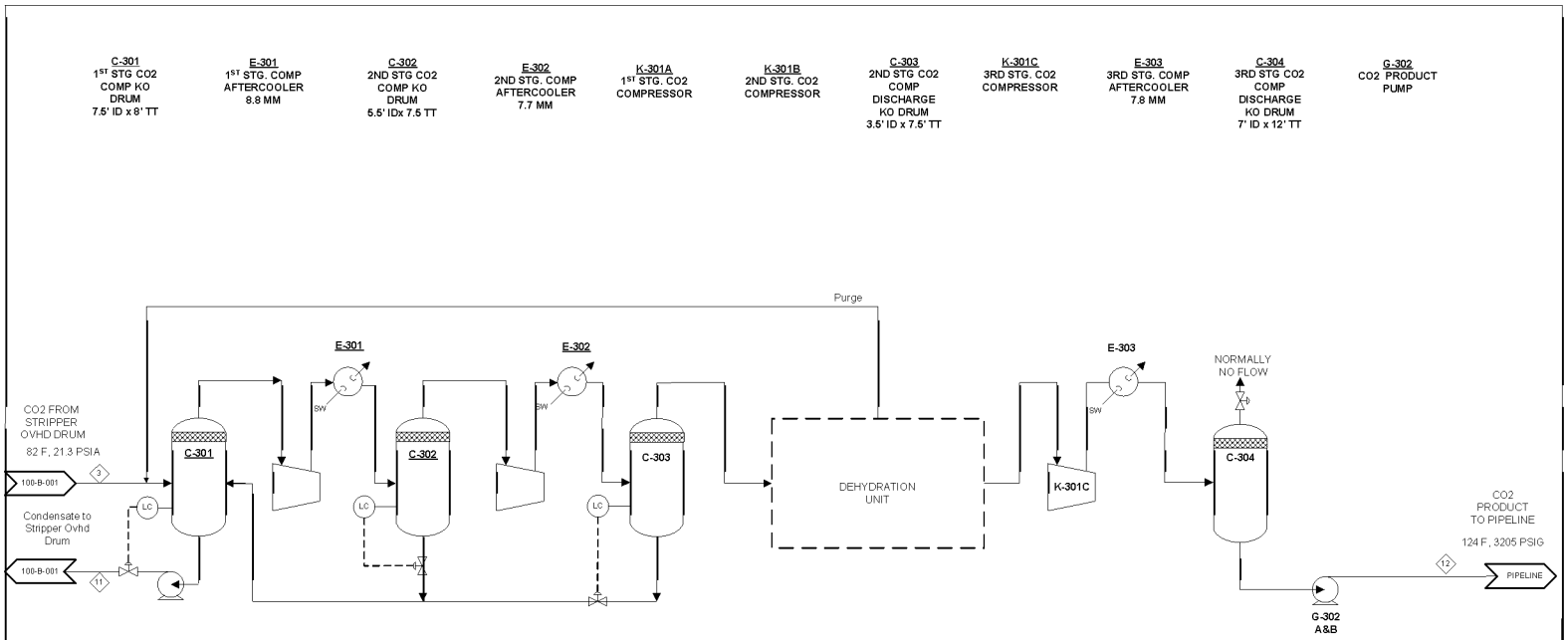
CO2 CAPTURE PROJECT
CO2 Removal from Power Plant Flue Gas
Cost Efficient Design and Integration Study

Process Flow Diagram
CO2 Recovery Plant-Base Case

Job No.	Drawing No.	Revision No.
00318	100-B-001	0

CO_2 Dehydration and Compression



Strm No.		3	11	12
Stream Name		Stripper Ovhd Vap	Condensate	CO2 Product
Component	MW	lbmol/hr	lbmol/hr	lbmol/hr
N2/Ar	28.15	0.7		0.7
O2	32.00	0.2		0.2
CO2	44.011	2973.1		2973.1
H2O	18.016	78.9	78.8	0.1
MEA	61.08	-		-
Total	Lbmols/hr	3052.9	78.8	2974.1
		132295	1419	130876
Actual Flow	GPM	-	2.6	327
Vapor Flow	MMscfd	28	-	27
Temp	°F	82	82	124

Notes:
1. Two identical trains are provided, each with compression and dehydration
2. MM=1000000 Btu/hr

Rev No.	Date	Revision	Engineer	Checked	Approval
1	4/10/2003		BDD		
0	1/10/2003		BDD		

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Process Flow Diagram
CO2 Compression Plant - Base Case

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00318	300-B-001	1

Reference Amine CO_2 Capture Plant – Performance and Cost Estimate

Total CO_2 Removal	2820 tones/day (86% Capture)
Installed Cost ($US)	$114 MM (Excluding Contingency)
Amine Capture	72%
CO_2 Compression	28%

Reference Amine CO_2 Capture Plant – Capital Cost Breakdown

Amine Plant

Absorber	27 %
Rich/Lean Exchanger	19 %
Reboiler & Other Heat Exchangers	15 %
Stripper	10 %
Feed Cooler	9 %
Flue Gas Blower	9 %
Pumps	8%
Others	3%

CO_2 Dehydration & Compression

Compressor	71 %
Supercritical CO_2 Pump	15 %
Dehydration Unit	6%
Others	8%

Reference Amine CO_2 Capture Plant – Performance and Cost Estimate

Plant Utility Consumptions	
Steam (6 barg) import, kg/hr	238,200
Electric power, kW	20,350
Seawater cooling duty, 10^6 kJ/hr	623
Condensate export, kg/hr	177,200

Catalyst and Chemical Consumptions	
85 wt% MEA, kg/hr	220
Activated carbon (amine grade), kg/d	114
Inhibitor consumption, kg/d	157
Anhydrous Na_2CO_3, kg/hr	168

Result Summary – Cost Reduction Ideas Screening and Trade-off Evaluations

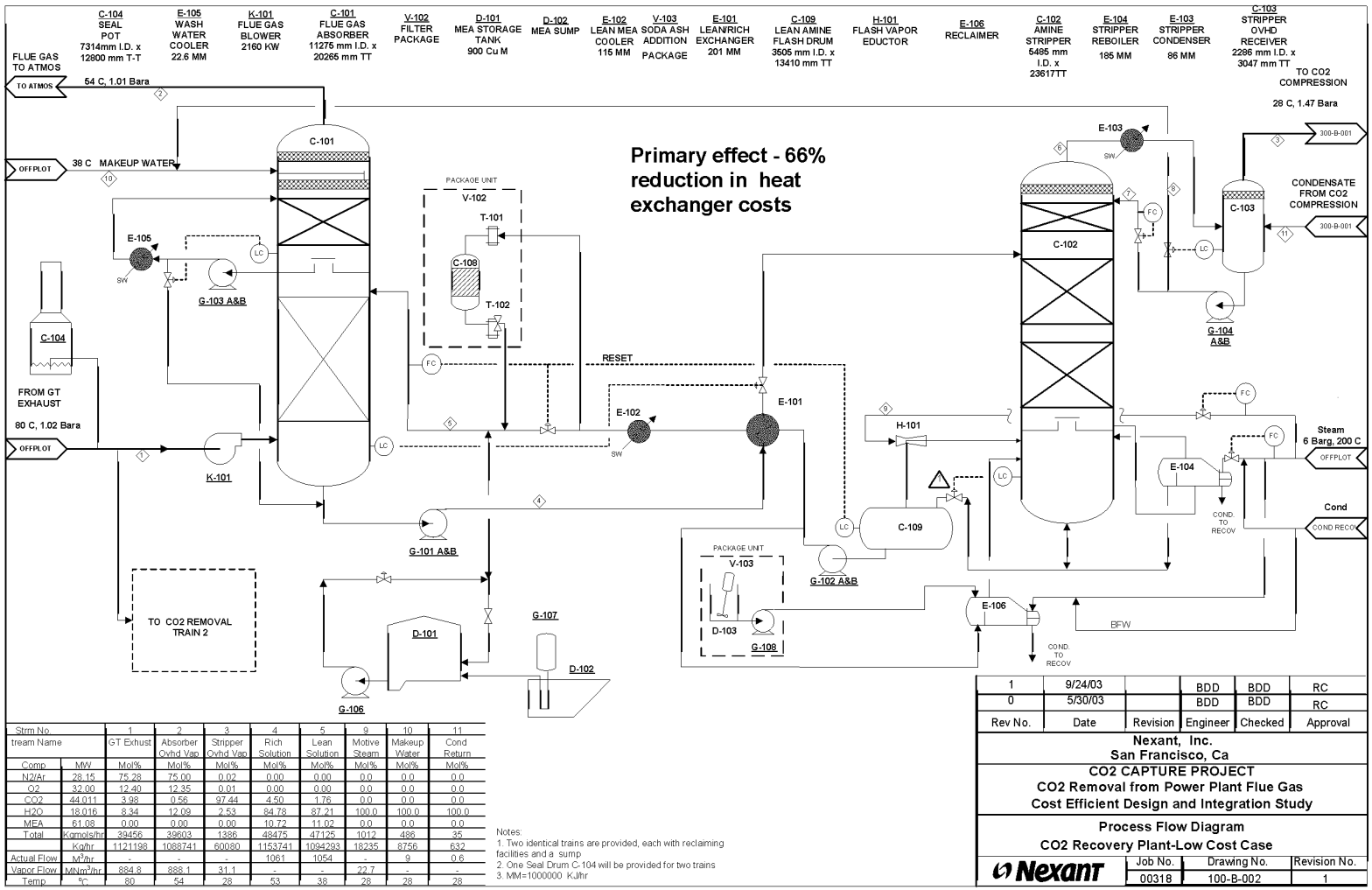
- Brainstorming exercise generated 64 ideas
- Thirty nine (39) were deemed either impractical, redundant, or simply lack of design/cost data for any meaningful engineering analysis
- Of the remaining ideas
  - 18 are related specifically to the amine design; trade-off analyses were performed, and 5 were selected for implementation in the Low-Cost amine design scheme
    - Use of plate & frame exchangers
    - Use of structured packing in absorber
    - Eliminate flue gas cooling
    - Flash hot lean amine solution and recycle steam to reboiler
    - Replace API pumps with ANSI pumps

Result Summary – Cost Reduction Ideas Screening and Trade-off Evaluations

- 7 are integration related, of which 2 were selected for implementation with the final Integrated Plant design.
  - Recycle portion of the HRSG flue gas to the gas turbine air compressor
  - Insert amine reboiler tube bundles directly into the HRSG

➢ Final design also replaces the two 50% trains CO_2 compression plant with a single 100% train.

Cost Reduction Design Changes – P&F Heat Exchangers



Strm No.		1	2	3	4	5	9	10	11
tream Name		GT Exhust	Absorber Ovhd Vap	Stripper Ovhd Vap	Rich Solution	Lean Solution	Motive Steam	Makeup Water	Cond Return
Comp	MW	Mol%	Mol%	Mol%	Mol%	Mol%	Mol%	Mol%	Mol%
N2/Ar	28.15	75.28	75.00	0.02	0.00	0.00	0.0	0.0	0.0
O2	32.00	12.40	12.35	0.01	0.00	0.00	0.0	0.0	0.0
CO2	44.011	3.98	0.56	97.44	4.50	1.76	0.0	0.0	0.0
H2O	18.016	8.34	12.09	2.53	84.78	87.21	100.0	100.0	100.0
MEA	61.08	0.00	0.00	0.00	10.72	11.02	0.0	0.0	0.0
Total	Kgmols/hr	39456	39603	1386	48475	47125	1012	486	35
	Kg/hr	1121198	1088741	60080	1153741	1094293	18235	8756	632
Actual Flow	M^3/hr	-	-	-	1061	1054	-	9	0.6
Vapor Flow	MNm^3/hr	884.8	888.1	31.1	-	-	22.7	-	-
Temp	°C	80	54	28	53	38	28	28	28

Notes:
1. Two identical trains are provided, each with reclaiming facilities and a sump
2. One Seal Drum C-104 will be provided for two trains
3. MM=1000000 KJ/hr

Rev No.	Date	Revision	Engineer	Checked	Approval
1	9/24/03		BDD	BDD	RC
0	5/30/03		BDD	BDD	RC

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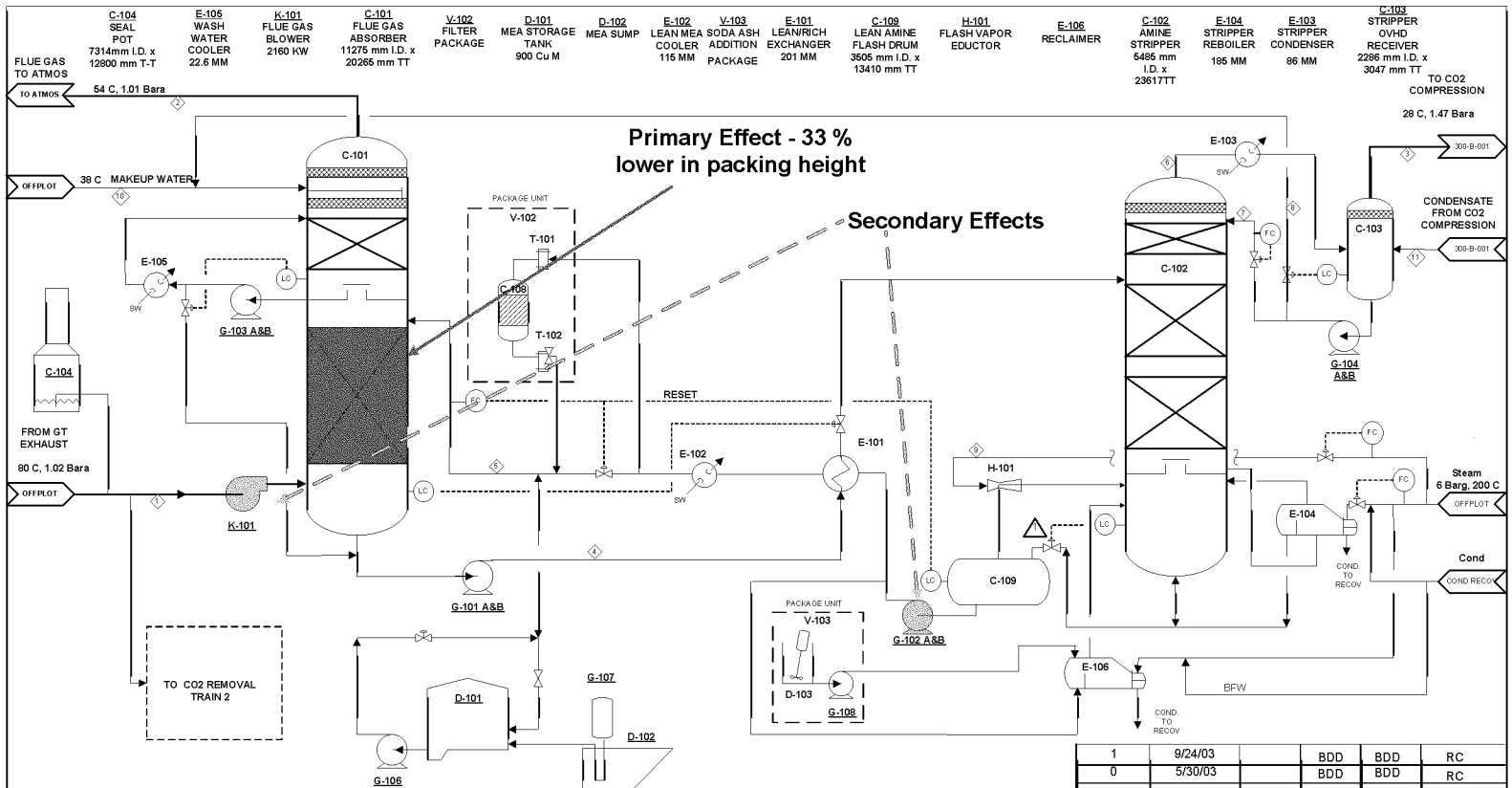
Cost Reduction Design Changes – Structured Packing



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O2	32.00	12.40	12.35	0.01	0.00	0.00	0.0	0.0	0.0
CO2	44.011	3.98	0.56	97.44	4.50	1.76	0.0	0.0	0.0
H2O	18.016	8.34	12.09	2.53	84.78	87.21	100.0	100.0	100.0
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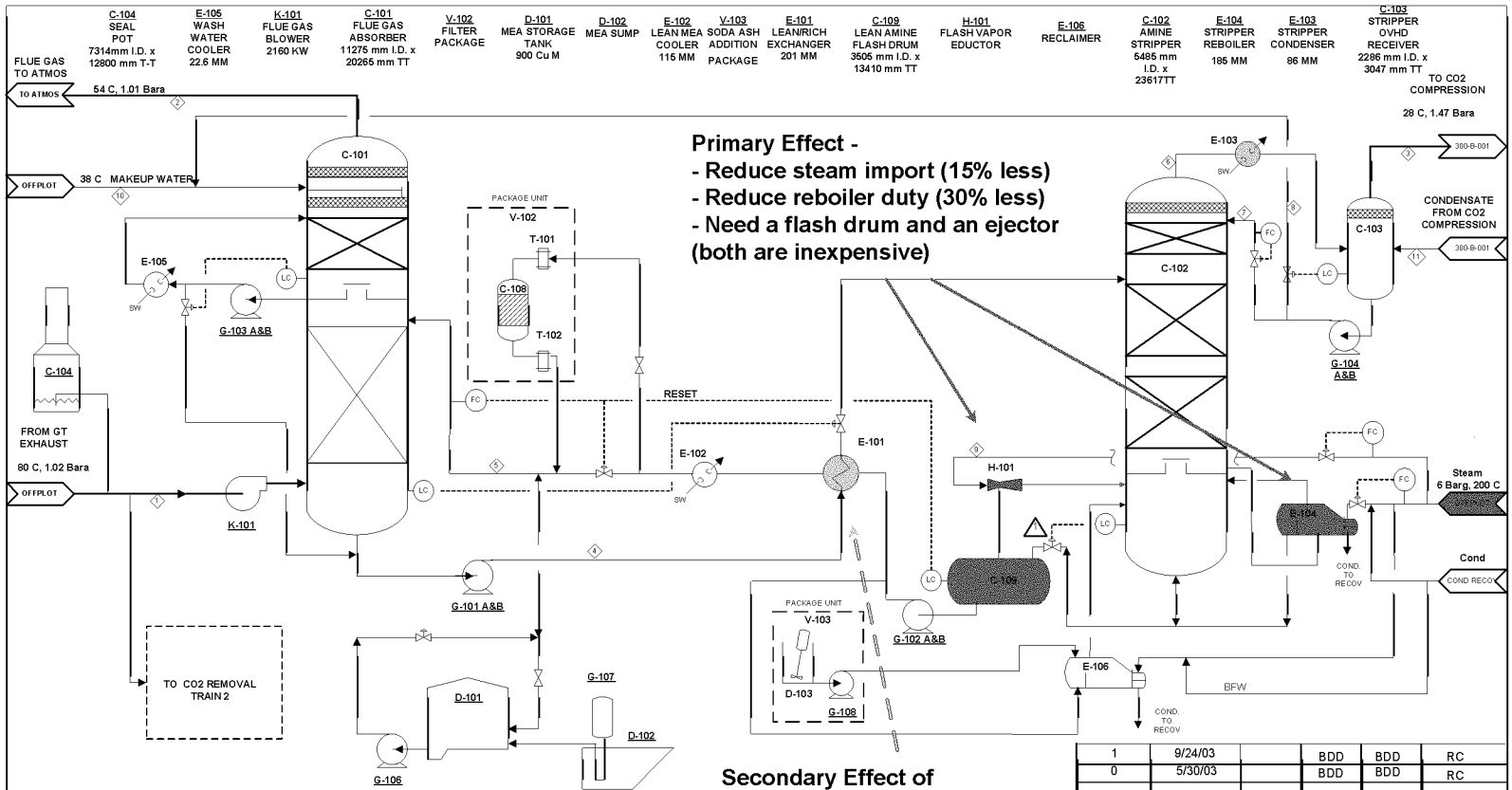
Cost Reduction Design Changes – Lean Amine Solution Flash



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Stream Name		GT Exhust	Absorber Ovhd Vap	Stripper Ovhd Vap	Rich Solution	Lean Solution	Motive Steam	Makeup Water	Cond Return
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N2/Ar	28.15	75.28	75.00	0.02	0.00	0.00	0.0	0.0	0.0
O2	32.00	12.40	12.35	0.01	0.00	0.00	0.0	0.0	0.0
CO2	44.011	3.98	0.56	97.44	4.50	1.76	0.0	0.0	0.0
H2O	18.018	8.34	12.09	2.53	84.78	87.21	100.0	100.0	100.0
MEA	61.08	0.00	0.00	0.00	10.72	11.02	0.0	0.0	0.0
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Vapor Flow	MNm^3/hr	884.8	888.1	31.1	-	-	22.7	-	-
Temp	°C	80	54	28	53	38	28	28	28

Result Summary

- Low Cost and Integrated Capture Plant Design, and Resulted CO_2 Capture Economics – to be discussed by Paul Hurst of BP.

Acknowledgements

Alfa Laval (Plate & Frame Exchangers)

Sulzer Chemtech USA (Structural Packing)

Sulzer Pumps (Supercritical CO_2 pump)

Elliott Turbonmachinery (CO_2 Compressor)

SDS Spray Drying Systems (Spray Gas Cooler)

GE (Gas Turbine)

PSB Industries, Inc. (CO_2 Dryer)

Howden Buffalo (Blower)

ATB Riva Calzoni, SpA (Vessels)