ALPHA MARINE
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Carbon Capture & Storage

FEASIBILITY STUDY ONBOARD CAR & TRUCK CARRIER – A VIABLE ROUTE

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Main Input, Data

Feasibility Study
Vessel's Main Particulars

31,000 m2 Pure Car & Track Carrier		
LENGTH	O.A.	168.06 m
BREADTH	MLD	28.00 m
DEADWEIGHT AT DESIGN DRAFT		11174 tn
Main Engine - Specifications		
TYPE		MAN B&W 7S50MC C82 (TIER III)
100 % LOAD (MCR)		11620 kW at 127 rpm
50 % LOAD		8716 kW at 115.4 RPM
SERVICE SPEED		19.6 Knots
Auxiliary Engine - Specifications		
TYPE		HIMSEN 7H21/32 3 x Sets
100 % LOAD (MCR)		1440 kW at 127 rpm
50 % LOAD		720 kW
Auxiliary Boiler - Specifications		
CAPACITY		1500 kg/h x 7.0 kg/cm^2
Exhaust Gas Economiser - Specifications		
CAPACITY		1100 kg/h x 7.0 kg/cm^2

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Feasibility Study
CCS Technology Overview & Specs

Main Specifications	
TYPE	AMINES BASED SOLUTION
CONNECTIONS	1xME + 3xD/Gs
CO_2 NET REMOVAL TARGET	40 %
E.G. FLOW @50 % M/E LOAD	55195 kg/h
E.G. FLOW @50 % D/G LOAD	4900 kg/h
E.G. FLOW TREATED	57200 kg/h
POWER DEMAND	1200 kW
STEAM DEMAND	1230 kg/h
LCO_2 STORAGE CONDITION	@14 bar, -30 °C
5 DAYS CAPACITY	2x80m^3 --> 160 m^3

CCS Equipment Integration

Feasibility Study
2D Arrangement

CCS Main Equipment Location	
ABSORBER TOWER REGENERATION TOWER EXH. GAS FAN CONDENSER REGEN. HEAT EXCHANGER REGEN. FILTER REGEN. AMINES TANK ABSORBING PUMP ABSORBING FILTER	CO_2 CAPTURE & SEPARATION RM
FILTERS & TANKS 1m³ 1st STAGE CHILLERS 1st STAGE COMPRESSOR 2nd STAGE CHILLERS 2nd STAGE COMPRESSOR HEAT EXCHANGERS	LIQUEFACTION RM
REGEN. AMINES PUMP AMINES PROCESS TANK 30m³ CONDENSATE PUMP	No.10 CAR DECK AMINES STORAGE RM
LCO_2 TANK 2x80m³	OPEN WEATHER DECK

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Feasibility Study
3D Arrangement

CCS Main Equipment Location	
ABSORBER TOWER REGENERATION TOWER EXH. GAS FAN CONDENSER REGEN. HEAT EXCHANGER REGEN. FILTER REGEN. AMINES TANK ABSORBING PUMP ABSORBING FILTER	CO_2 CAPTURE & SEPARATION RM
FILTERS & TANKS 1m³ 1st STAGE CHILLERS 1st STAGE COMPRESSOR 2nd STAGE CHILLERS 2nd STAGE COMPRESSOR HEAT EXCHANGERS	LIQUEFACTION RM
REGEN. AMINES PUMP AMINES PROCESS TANK 30m³ CONDENSATE PUMP	No.10 CAR DECK AMINES STORAGE RM
LCO_2 TANK 2x80m³	OPEN WEATHER DECK

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Feasibility Study
CO_2 Capture, Separation & Amines Room

- One new casing shall be constructed attached to the existing.
- Location: Between Fr. 35-Fr. 53, Port Side
- The height will be approx. 15m above Upper Deck.
- Part of the No. 10 Car Deck shall be used for the installation of the amine process tank and associated pumps.
- There are no visibility problems at the navigation lights and radars from the new structures' installation.

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Feasibility Study
Liquefaction Room

- One new deckhouse shall be constructed above the superstructure of the upper deck .
- Location: Between Fr. 23-Fr. 45, L2P-L7S.
- The new structure shall be comprised of two deck to reduce its breadth and avoid significant changes to Equipment Number.
- The bottom deck will be elevated 2.5m from the A Deck in order to avoid clashes with the existing vents.

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Feasibility Study
LCO_2 Tanks

- For the CO_2 storage, two (2) tanks (80m³ each) have been used for redundancy and easier installation.
- Tanks volume is equivalent to 5 days storage capacity.
- They will be installed on the Upper Deck, one port and one starboard side, between Frames 153-165.
- It is also an option to use portable removable 20 ft container tanks enabling onshore transfer through appropriate trucks.

CCS Piping Arrangement

Feasibility Study
Piping Arrangement – Material Specifications

Piping - Material Specifications	
EXH. GAS	DUBLEX 2205 STAINLESS STEEL
AMINES SOLUTION	SUS316
CO_2 LIQUEFACTION	CORROSION RESISTANT ALLOY
CO_2 TRANSPORTATION	CARBON STEEL
STEAM	CARBON STEEL

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Feasibility Study

CO_2 Capture, Separation & Amines Room - Piping Arrangement

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Feasibility Study
Liquefaction Room – Piping Arrangement

Feasibility Study
LCO_2 Tks - Piping Arrangement

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Technical Analysis

Feasibility Study
Electric Balance Analysis

- The electric power consumption of the CCS depends on the amount of the treated exhaust gases.
- At the design condition of the system (ME at 50% and 1xDG at 50%) the consumption is **1200kW** and the CO_2 reduction is 40%.
- Considering that all D/Gs can operate at 90% load, the available power for the installation of the EGCS is indicated in the following table:

No.	Load Condition	Total Load (kW)	No. of Running D/Gs	Load Factor (%)
1	Sea W/O Car Dk Fan	769.8+1220=**1989.8**	1 / **2**	57.0 / **73.7%**
2	Sea W/ Car Dk Fan	1358.1+1071.9=**2430**	2 / **2**	50.3 / **90.0%**
3	Port In/Out	3485.9+159.1=**3645**	3 / **3**	86.1 / **90.0%**
4	Load/Unload	1500.6+350=**1850**	2 / **2**	55.6 / **68.5%**
5	Harbor W/O Car Dk Fan	552.8+160=**712.8**	1 / **1**	40.9 / **52.8%**
6	Harbor W/ Car Dk Fan	1141.1+290=**1431.1**	2 / **2**	42.3 / **53.0%**

- In conclusion, at loading conditions No.2&3 the system will have to operate at a lower rate due to the limited power available onboard and subsequently the CO_2 capture rate will drop.

Feasibility Study
Steam Balance Analysis

- For the separation of the CO2 from the amines steam is supplied into the Regeneration tower.
- The CCS will operate at **50 % load** of M/E & D/Gs.
- The subject vessel is equipped with one (1) Auxiliary Boiler possible to provide **1500 kg/h**, and one (1) Exhaust Gas Economizer, providing **1100 kg/h** in the exhaust part.
- The average steam consumption of the CCS is **1230 kg/h**.

No.	Loading Condition	Onboard Steam Consumption (kg/h)	Aux. Boiler - Steam @ 100% Load (kg/h)	Exh. Econom - Steam @ 50% Load (kg/h)	Available Steam (kg/h)
1	Navigation	1101	1500	812	1211<1230

- It can be assumed that the available steam onboard during the Navigation Condition is marginally sufficient for the CCS .

Feasibility Study
Lightweight Assessment

Summary	Weight [t]	LCG (fm AP) [m]	TCG (- to port/ + to stbd side) [m]	VCG (fm BL) [m]	W x LCG [txm]	W x TCG [txm]	W x VCG [txm]
Existing Lightship	11842.000	-7.190	-0.010	15.810	-85144.0	-118.4	187222.0
New Lightship	12160.065	-8.032	-0.135	16.356	-97668.5	-1647.3	198891.1
% Difference	**2.69% LW**	**-0.55% LBP**	**0.45% B**	**3.45% VCG**			

- The introduction of CCS equipment and associated structures adds a substantial dry weight of approximately **266.65 tons** to the vessel, inevitably leading to a reduction in cargo-carrying capacity.
- In addition, one new room shall be constructed on the No.10 car deck leading to a 0.16 % reduction of the total cars' capacity (equivalent to approx. **8 cars**).
- The LW difference is **2.69%>2%** and the VCG difference is **3.45%>1%**, thus a new inclining experiment will have to take place.

Feasibility Study
Stability Assessment

Loading Condition	Problem	Solution
LCO4 BALLAST CONDITION ARRIVAL	Heel: 2.97p deg	• Three Port WBTKs filling reduced by 20% • One Starboard WBTK filling increased by 10%
LCO5-RT43 CAR LOADING CONDITION DEPARTURE	Draft Mid: 8.825>8.70 Heel: 4.07p deg	• Three Port WBTKs filling reduced by 20% • One Starboard WBTK filling reduced by 20%
LC12-RT43 + SMALL TRUCK CONDITION ARRIVAL	Draft Mid: 8.772>8.70 Heel: 9.69p deg GZ criteria: not pass Weather Criteria: not pass	• DK10 CAR: 534MT → 310MT • Two Port WBTKs filling reduced by 40% • One Starboard WBTK filling reduced by 15%

The implementation of CCS will give rise to the subsequent issues:

- **Under ballast condition,** heel becomes problematic. This can be addressed by reducing the filling percentage of No.2~No.5 WBTks, as indicated.

- **Under car loading departure condition,** heel and mid draft become also problematic. This can be addressed by reducing again the filling percentage of No.2~No.4 WBTks, as indicated.

- **During car and small truck loading arrival condition**, the permissible mean draft, heel exceeds prescribed limits. Additionally, GZ and weather criteria are not fulfilled. These issues can be resolved by reducing the cargo capacity on No.10 Deck by 224 MT and by decreasing the filling percentage of No.3~No.4 WBTks, as indicated.

Summary

Feasibility Study
Technical Conclusions

1. **Large footprint:** in order to avoid changes to the EN, the width of the new superstructures should be lower than B/4=7m.

2. **Cargo capacity reduction:** the introduction of CCS equipment and associated structures adds a substantial weight, resulting in decrease of cargo capacity.

3. **Lightweight re-evaluation:** the permissible LW and VCG difference exceed prescribed limits, thus a new inclining experiment is unavoidable.

4. **Stability re-evaluation:** the vessel remains safe from structural point of view. Nevertheless, the permissible mean draft and heel exceed prescribed limits, while the GZ and weather criteria are not fulfilled in some loading conditions. These issues can be resolved by reducing the cargo capacity and the filling percentage of WBTks. In any case the revision of loading and damage stability manuals in imperative.

5. **Shaft alignment analysis:** typically, when a large weight is added into a ship, it can lead to hull deformations, resulting in load changes on the shaft bearings and put stress on the shaft itself. Further, elaboration is required during detailed engineering.

6. **Insufficient electric power and steam availability:** under certain loading conditions, poses operation challenges.

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LET'S TALK

Feel free to contact us at mail@alphamrn.com for any questions or further information you may need. We are committed to provide response to any technical inquiry within 24 hours.

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Thank You!

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