DANUBIA KREUZFAHRTEN GMBH

PURE BLUE

Interreg
EUROPEAN UNION
Danube Transnational Programme
GRENDEL

Consulting Service No. 1 On-Board Sewage Treatment

GRENDEL – Green and Efficient Danube Fleet

Final Event , 29.10.2020

R. Comanici

Project co-funded by European Union Funds (ERDF, IPA)

Scope of work

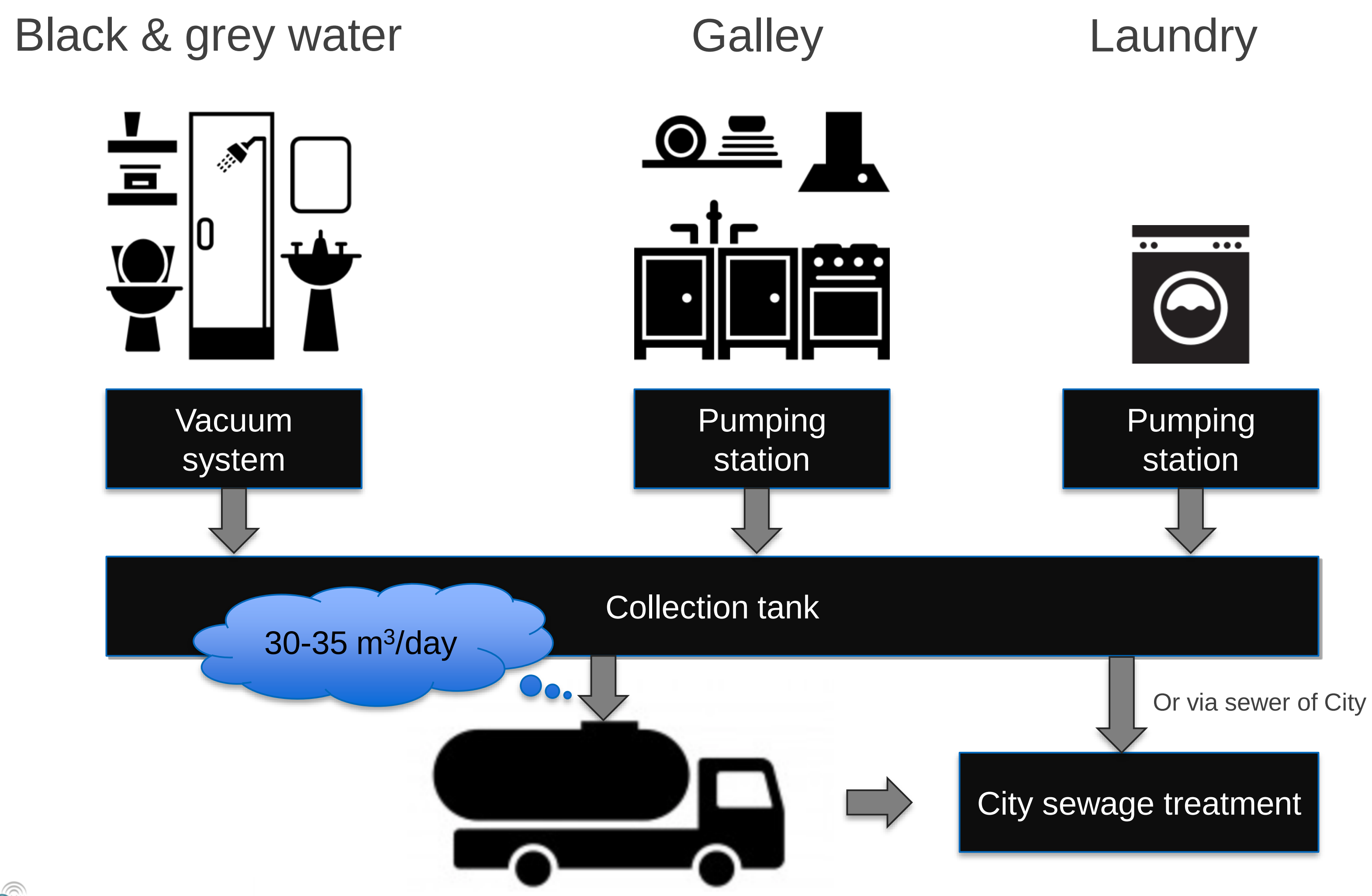
General:

Transitional provisions of ES-TRIN (Chapter 32) in general grant continuous use of on-board treatment plants installed before the entering into force of harmonised European legislation.

Detail:

- whether it is technically possible and economically feasible to install up-to-date on-board sewage treatment plants on those vessels which are so far equipped with collection tanks;
- whether it is technically possible and economically feasible to upgrade existing on-board sewage treatment plants to current outflow emission standards.

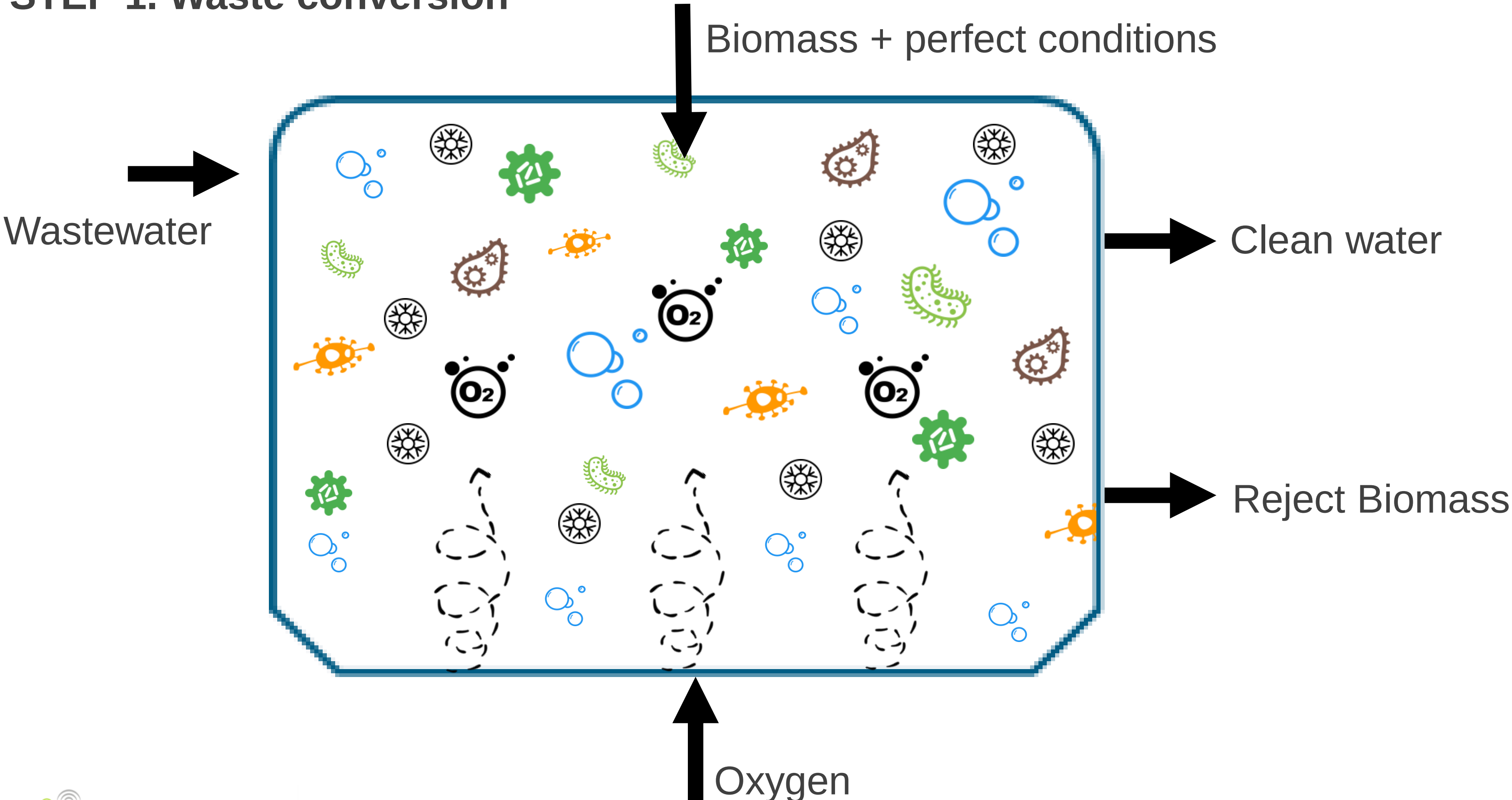
General information wastewater disposal to shore



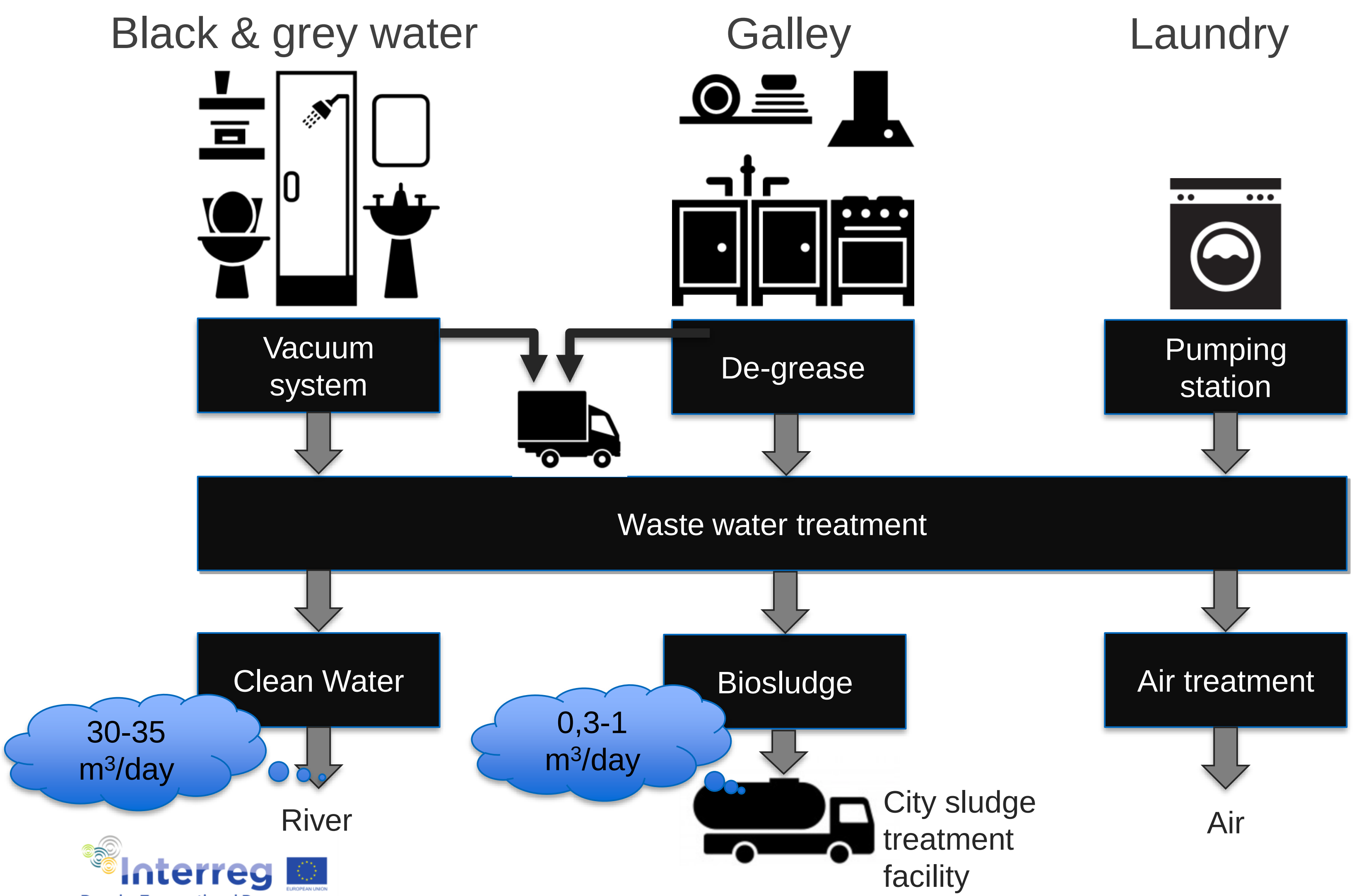
Project co-funded by European Union Funds (ERDF, IPA)

General information wastewater On-board treatment

STEP 1. Waste conversion



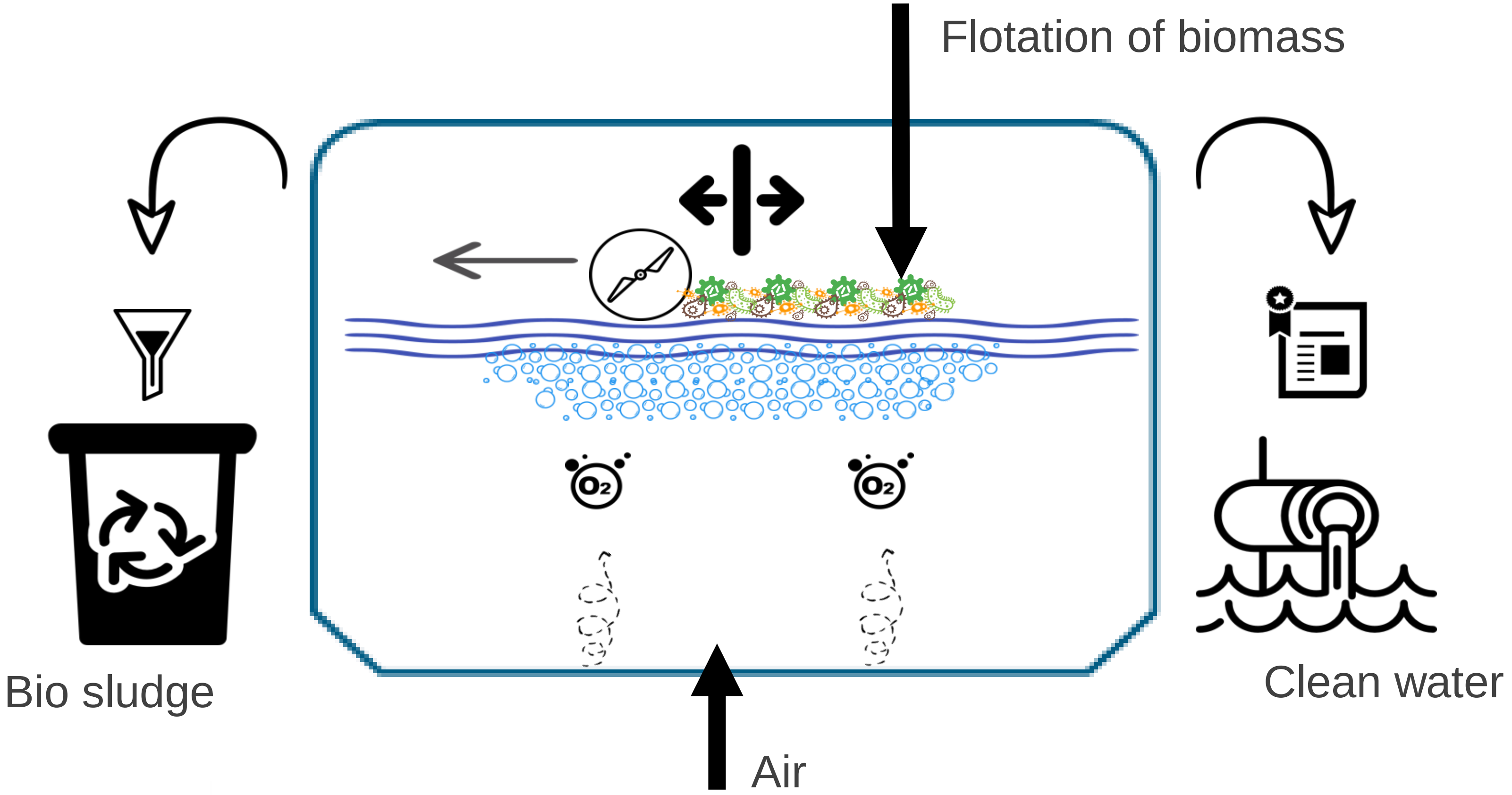
General information wastewater On-board treatment



Carrier MBBR INNOPACK^{++}	MBR
Separation of water and sludge: membranes?	
No Flotation separation	Yes Membranes
No clogging possible Free flow throughout the unit No physical barrier Automated control and cleaning of DAF System	Vulnerable to clogging & blockage with high loads of COD, oil, fat, grease, solids Membrane = physical barrier Regular cleaning and operator knowledge necessary
Pre-screening needed?	
No	Yes
No storage/disposal needed	Storage/disposal for pre-screened waste
Grease Trap needed?	
Optional: to protect long pipe lines or make WWTP smaller	Yes to prevent membrane clogging
5-20 l of waste per day	500-2000 l waste per day
Clean In Place?	
No	Yes
Treatable waste water	
Galley water: optional, for compact reactor design	Galley water: if screened and grease is removed
Black water: direct	Black water: if screened
Grey water: direct	Grey water: if screened
Laundry water: direct	Laundry water: if screened
Reason: Innopack^{++} not susceptible to blockage	Reason: susceptible to blockages
Bio-technology	
Biofilm on carrier material	Suspended biomass (Active Sludge)
More active biomass	Less active Biomass on-board
Less energy consumption Better oxygen transfer	Higher energy consumption Lower oxygen transfer
No recirculation	Needs recirculation
No consumables	Every 3-4 years cost for new membranes
Waste Sludge	
3 - 5 times more concentrated = lower waste sludge volume = lower disposal cost	3 – 5 times less concentrated = more sludge volume
less storage required	more storage required (at least 3 times more)
Yearly start-up / shut down	
No CIP	Yearly CIP and costs
Direct start after inter-season break	Gradual start-up
No operator time needed	Service time

General information wastewater On-board treatment

STEP 2. Separation



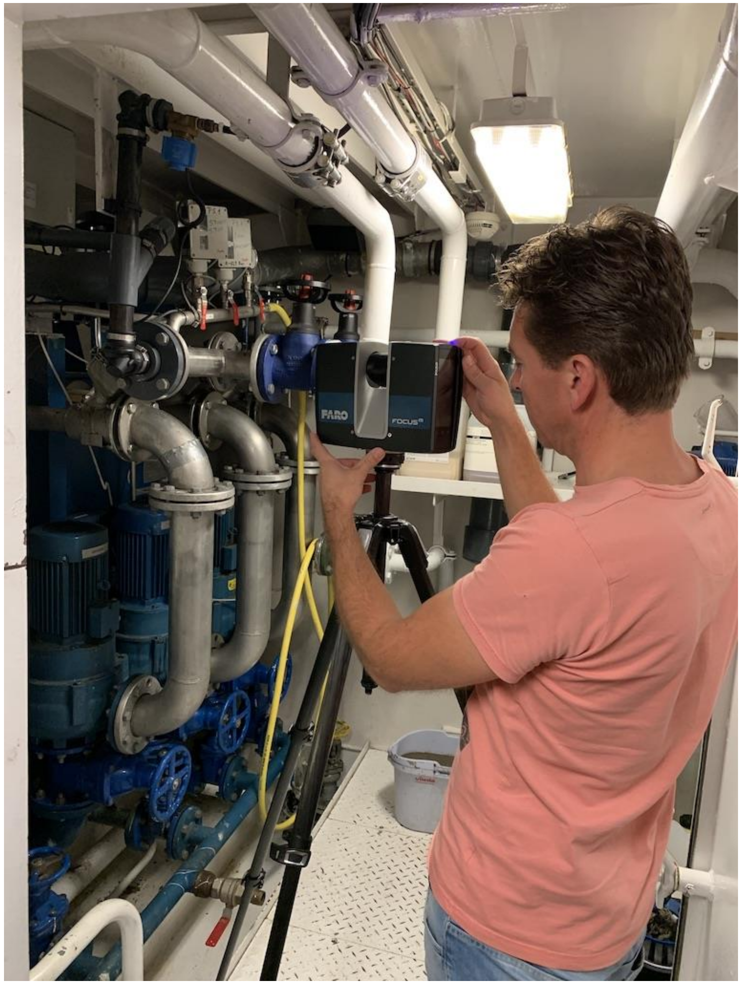
Assessment Amadeus Rhapsody

Vessel of Lot 1. Typical situation: Collection of wastewater and disposal to shore.

Location: Budapest

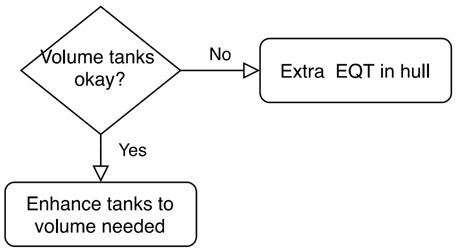
Attended: R. Comanici, , A. de Mul, C. Mijnders

Inspection report 17-9-2019
Assessment with 3 D scanner

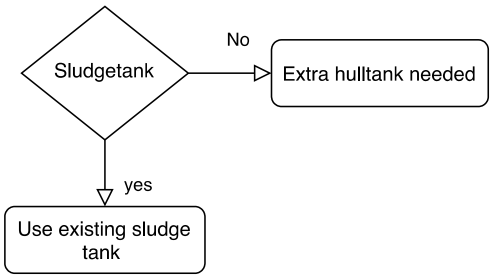


Solution to upgrade existing unit

Volume

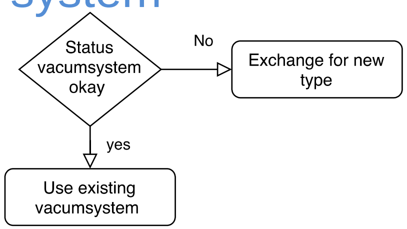


Sludge

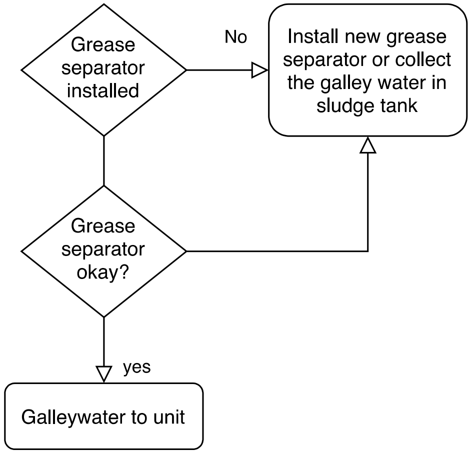


1. Location separator
2. Power supply
3. Air outlet
4. Planning

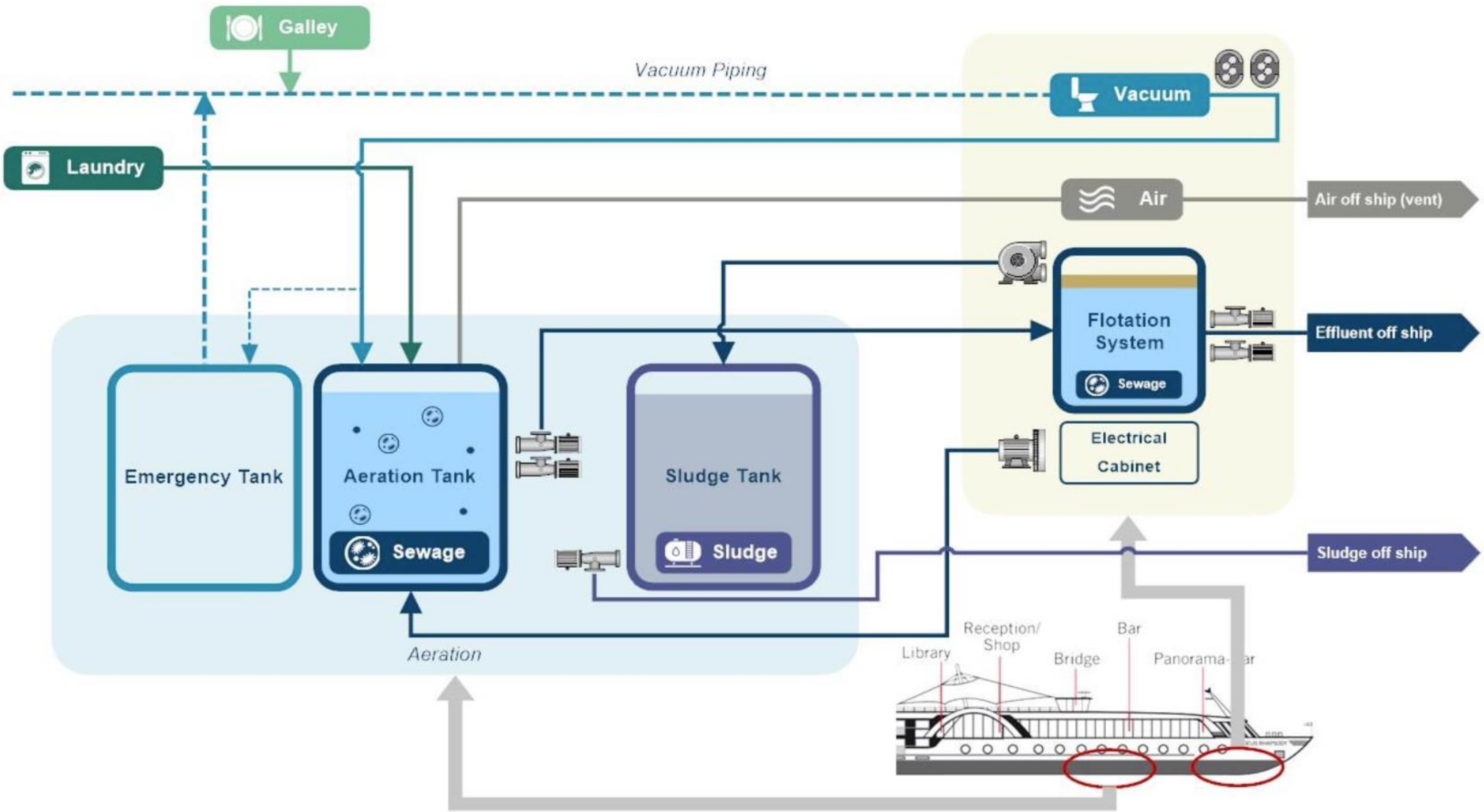
Vacum system



Grease

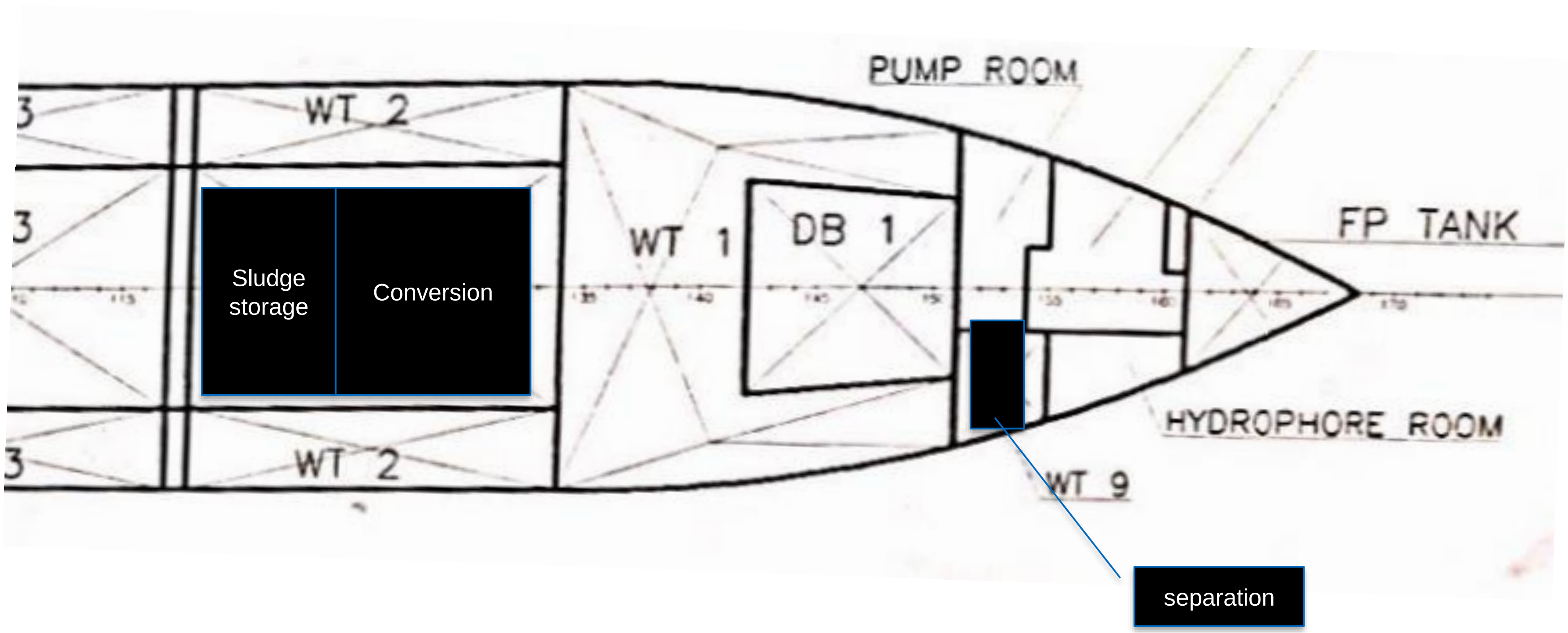


Possible solution



Project co-funded by European Union Funds (ERDF, IPA)

Possible solution



Possible solution

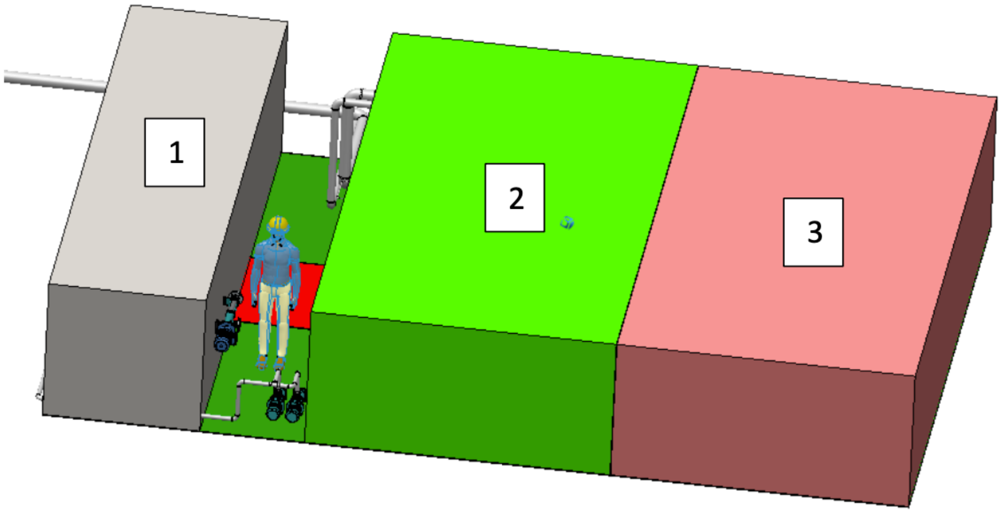


Figure 7: Close view of the tanks and equipment arrangement.

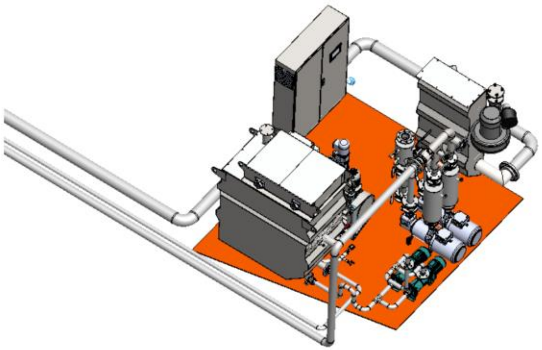


Figure 6: Pre-design.

Financial evaluation

Change in annual operational costs due to changed discharge cycles in comparison to collection tank

	Sewageplant			Collection	
Investment unit	€ 319.550			€ -	
Investment yard	€ 150.000			€ 50.000	(treatment tanks)
Lifetime	15	years		15	years
Deprication over lifetime	€ 31.303	per year		€ 3.333	per year
Annual maintenance cost incl. consumables ect.	€ 15.000	per year		€ 2.500	per year (cleaning)
Sludge disposal	246	m3 sludge per year		€ -	
Sludge disposal cost	€ 25	per m3		€ -	
Annual sludgecost	€ 6.159	per year		€ -	
Water collected per year				8.213	per year
Water disposal cost (avr)				€ 20	per m3
Disposal cost per year				€ 164.250	per year
Additional cost for waiting and schedule changes				€ 15.000	per year
Total annual cost	**€ 52.463**			**€ 185.083**	
Price per m3/year	**€ 6,39**	**per m3 treated**		**€ 22,54**	**per m3 disposed**
ROI	**3,54**	**year**			

Lessons learned

CAPACITY OF WASTEWATER TREATMENT AND THE LOADING PATTERNS

INFLUENCES OF DIFFERENT PROCESSES ON BOARD

MAINTENANCE AND TRAINING OF ENGINEERS

Main facts

Wishlist key elements of the Future Wastewater Treatment

- Capable to treat > 70 kg COD per day
- Capable to treat > 35 m3 water per day
- Footprint of max. 15 m2 (typical for the old installations)
- Maximum volume of water on board of 14 m3 (in installation and incl. buffer)
- Easy to operate, no specialists needed on board
- Easy to maintain, no tank cleanings in wintertime
- Interactive with grease separator
- No pre-treatment and buffering
- Low sludge production
- Online accessible for contact with experts
- Sustainable treatment ad green label
- No operational implications during winterstop
- Effluent of the unit must be always good.

Lessons learned

- Old type sewage treatment plants are designed on old parameters and for half of the real pollution. Because of that reason the do not function well, effluent is still polluted and the unit will be blocked rapidly. That's the reason to shut down the unit;
- Due to the high incidental loads during the day the capacity needs to be 100% higher. This implies that most of the times the floorspace of the old unit will not be big enough. Either you need more space (room) or you will need more treatment capacity per m^2;
- Processes in galley and laundry influence performance of sewage plant substantial. The need for a proper treatment is high;
- Foodcompactors increase the load substantially and are overloading the sewage plants;
- Cleaning agents could influence performance of sewage plant substantial. The use of chlorine is prohibited;
- Watertreatment is too complex for engineers and they need backup from professionals;
- Biological processes are sustainable if chemicals will be avoided. Sludge treatment chain could be enhanced and made more sustainable;
- Membranesystems are more complex, use more energy, make more sludge, have a higher demand for follow up, increases the annual maintenance cost and are therefor <u>not</u> the greenest choice;
- Buffertanks will increase the total weight of the ship which will influence the fuel consumption.

Knowledge transfer:
How to make a retrofit possible

Step 1 Inventory:

- Make a good inventory of the water flows
- Where could the water be processed, how much water is constant on board to store?
- How much space is available for the installation?

Step 2 Preliminairy sketch:

Options:

1. New technology in old installation
2. New installation (prefab) at old location
3. New installation (prefab) at new location
4. New hull made installation at new location

Step 3 Choice of technology.

- Chemical proces
- Biological proces without membranes
- Biological proces with membranes

Knowledge transfer:
How to make a retrofit possible

Step 4 Rate of automation

- Local or online control
- Full watermanagement will increase sustainability

Step 5 Decision making

- Installation manufacturer based on green record. Innovation is key in retrofit…
- Shiphard needed? If yes, which one,
- Invest in project coördinator

Step 6 Follow up

- Invest in good training
- Invest in spare parts and service contracts

Green Award inland cruise vessels for PureBlue Water

AIM OF THE WORK

Main objective: structural improvements based on the design of "Amadeus Silver III" in order to achieve a reduction of noise and vibration levels in the crew quarters of an advanced sister-ship.

The technical investigation includes:

- **noise and vibration measurements in representative positions aboard "Amadeus Silver III"**
- **creation of mathematical models of "Amadeus Silver III" to perform a dynamic finite element analysis for the prediction of vibration levels at low frequencies and a statistical energy analysis for the prediction of noise levels**
- **analysis of possible improvement measures taking into account a significant reduction of noise and vibration values and an optimization of the structural design considering low weight solutions**
- **derivation of recommendations for concrete structural improvements**
- **identification of remaining sources of external noise**
- **recommendation for reducing noise emissions from these sources**

AIM OF THE WORK

After the technical investigation, three options have been analyzed and they are listed below:

Option 01: Based on the findings of the main technical study the supplier shall elaborate recommendations for possible retrofitting measures with view to improving noise and vibration levels of the existing fleet.

- Option 02: Based on the findings of the main technical study the supplier shall guide the design office respectively the building yard of the next newbuilding of Danubia Kreuzfahrten GmbH during the structural design and actual building phase in order to ensure appropriate implementation of the recommended measures. The supplier shall propose in particular a sufficient number of on-site surveys and milestones where the supplier's intervention would seem to be necessary, including in any case a final measurement of noise and vibration levels after completion of the vessel and comparison with calculated values.

- Option 03: The supplier shall conduct a technical study using the models created in the main technical study with the objective of reducing the external noise of the vessel stationary at a berth and assuming the presence of electric shore connection. This study shall in particular address identification of remaining sources of external noise and recommendations for reducing the noise emissions from these sources.

MAIN TECHNICAL STUDY

- Calibration of the developed numerical models with the data measured on board during the performed river trials.
- Design of structural improvements and insulation improvements for vibro-acoustic levels mitigation to be implemented in the Lüftner Cruise similar ship (actually under construction).
- Test of the studied improvements by performing iterative acoustic and FE analysis.
- Evaluation of achieved benefits in terms of noise and vibration levels mitigation

EXTERNAL NOISE LEVELS LIMITS

ES-TRIN

Chapter 8
Engine design

Article 8.10
Noise emitted by vessels

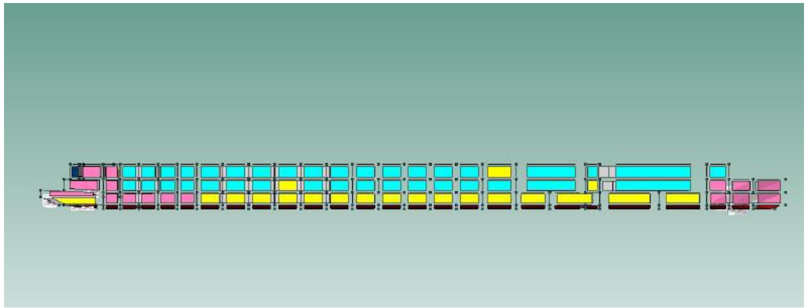
1. The noise produced by a vessel under way, and in particular the engine air intake and exhaust noises, shall be damped by using appropriate means.

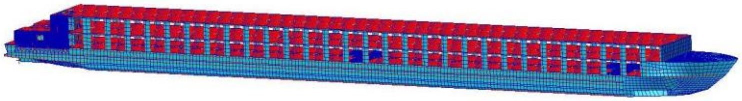
2. The noise generated by a vessel under way shall not exceed 75 dB(A) at a lateral distance of 25 m from the ship's side.

3. Apart from transhipment operations the noise generated by a stationary vessel shall not exceed 65 dB(A) at a lateral distance of 25 m from the ship's side.

CRITICAL AREAS AND CALIBRATED MODELS

Critical areas will be investigated with both FEM-SEA analysis and during the measurement campaign on board.
Starting from the general arrangement, scantling plan, main frame, insulation and floor plans, the SEA and FEM models of the Amadeus fleet similar ship has been realized.





AMADEUS SILVER III

Dedicated measurements campaign on similar vessels of Amadeus SIlver III have been performed in order to have a global overview of noise and vibration levels on board vessel in previously defined critical areas.
Those data have been used to calibrated the SEA-FEM models to represent the actual status of noise and vibration levels on board.
Calculations have been performed considering the main exciting sources as well as main engines, propellers, DD.GG. and HVAC and Chiller units.

Structure borne noise

SBN levels measurements have been performed on main propulsion machinery and used for calibrating SEA-FEM models for vibro-acoustic analysis.
Some measurements are reported in the following.
On Y-axis, the measured dB (ref. 5e-8 m/s) are shown for longitudinal direction (red curve), transverse direction (blue curve) and vertical direction (green curve). Third octave frequency bands (Hz) are shown on X-axis.

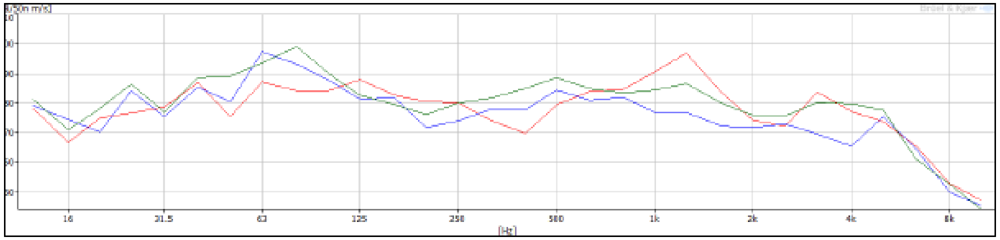


Figure 74 – Measured SBN level spectrum on DD.GG. alternator

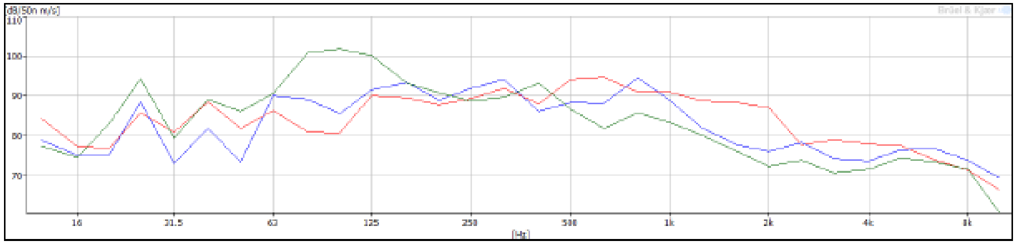


Figure 78 – Measured SBN level spectrum on port side DD.GG. head

AMADEUS SILVER III – MEASUREMENTS

Measurements have been performed in accordance with developed test protocol and in accordance with the time available for the measurements due to vessel schedule.
Measurements location are shown in the following pictures:

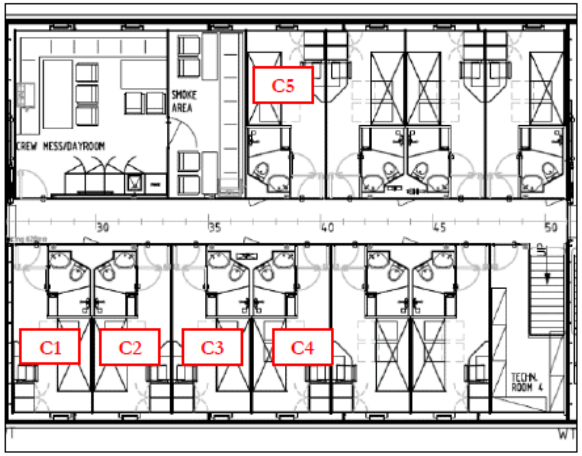


Figure 38 – Crew accommodation areas on Haydn deck aft

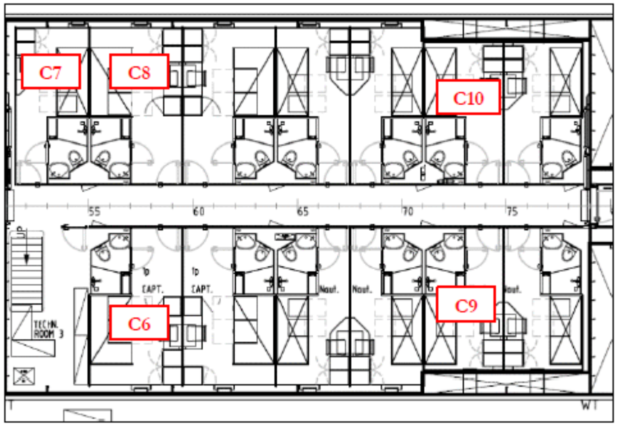


Figure 39 – Crew accommodation areas on Haydn deck middle

AMADEUS SILVER III – MEASUREMENTS

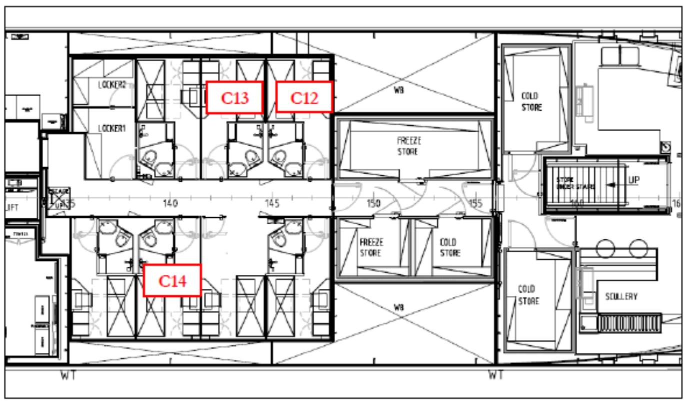


Figure 40 – Crew accommodation areas on Haydn deck fore

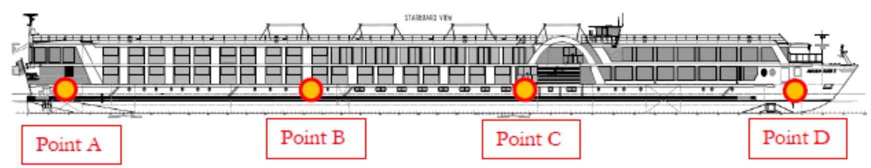


Figure 41 – Overview of the external noise measurement points (each point is at 25mt from the berthing side of the vessel)

External noise measurements have been performed to evaluate the environmental noise generated by the ship.

On board measured dB(A) noise levels upstream

Area	Deck	Measured dB(A) noise level
Crew cabin – C1	Haydn	60.2
Crew cabin – C2	Haydn	58.2
Crew cabin – C3	Haydn	54.9
Crew cabin – C10	Haydn	49.1

Table 1 – Measured noise levels in crew quarters, ship cruising upstream

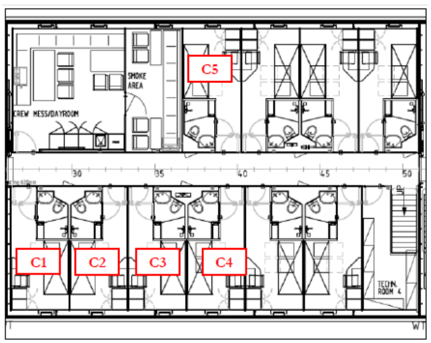
Measured vibration levels

Area	Deck	Measured o.a. rms vibration level (mm/s)
Crew cabin – C1	Haydn	0.80
Crew cabin – C2	Haydn	0.52
Crew cabin – C3	Haydn	0.51
Crew cabin – C4	Haydn	1.10
Crew cabin – C5	Haydn	0.75
Crew cabin – C6	Haydn	0.40
Crew cabin – C7	Haydn	0.60
Crew cabin – C8	Haydn	0.40
Crew cabin – C9	Haydn	0.20
Crew cabin – C10	Haydn	0.20
Crew cabin – C11	Haydn	0.20
Crew cabin – C12	Haydn	0.10
Crew cabin – C13	Haydn	0.20
Crew cabin – C14	Haydn	0.30

Table 2 – Measured vibration levels in crew quarters

Some noise spectra upstream

the measured dB(A) noise levels are shown on Y-axis while X-axis shows the third octave frequency band



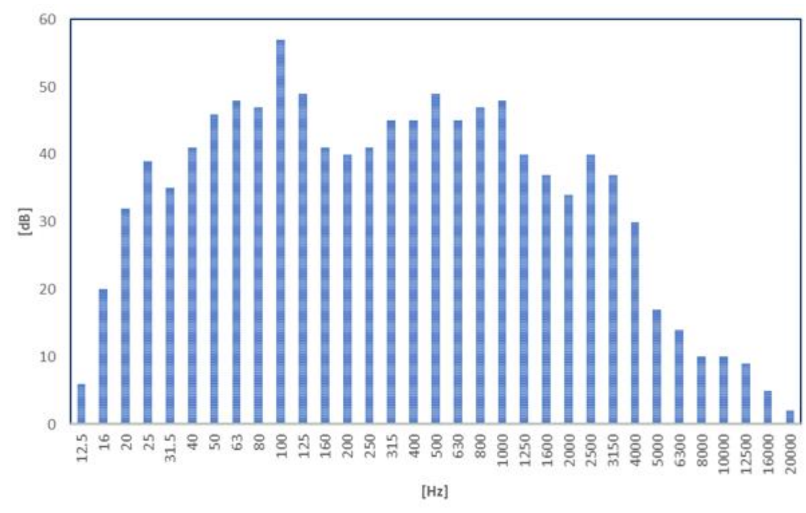


Figure 1 — Measured noise level spectrum Crew Cabin C1, 60.2 dB(A)

CALIBRATED FEM MODEL - VIBRATION LEVELS

Measured data on Amadeus Silver III have been used to calibrate the FEM models as per following table of vibration levels:

Cabin	Deck	Vibration level measured on board [overall weighted mm/s]	FEM maximum calculated vibration level [overall weighted mm/s]
Crew cabin – C1	Haydn	0.80	0.72
Crew cabin – C2	Haydn	0.52	0.55
Crew cabin – C3	Haydn	0.51	0.50
Crew cabin – C4	Haydn	1.10	0.95
Crew cabin – C5	Haydn	0.75	0.81

Table 8 – Comparison between measured and calculated noise levels in crew cabins aft ship area

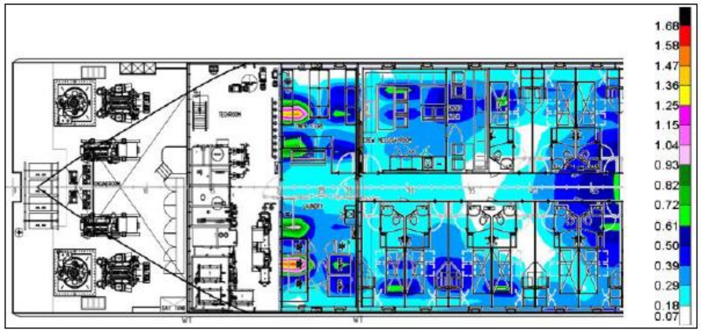
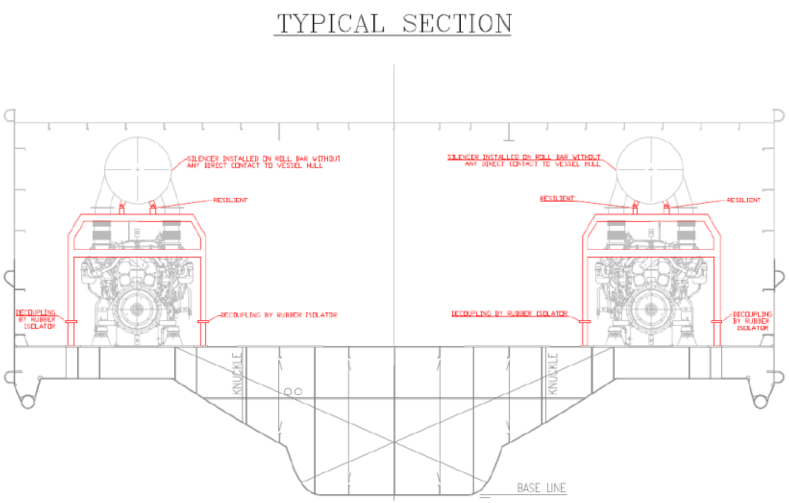
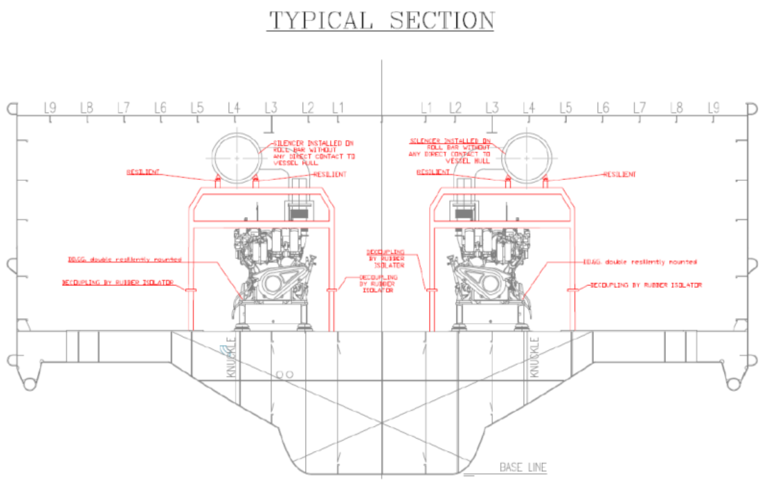


Figure 89 – Calculated vibration level in aft crew accommodation areas

PROPOSALS OF IMPROVEMENTS – AMADEUS SILVER III



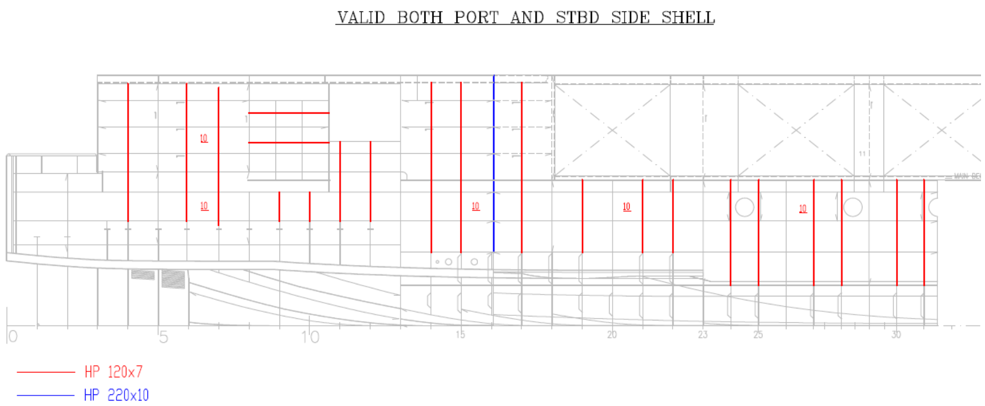
Proposal of improvements for main propulsion engines silencer/exhaust piping installation



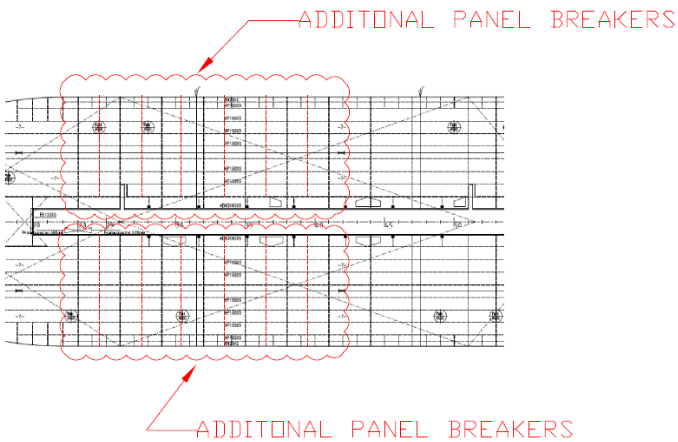
Proposal of improvements for DD.GG. silencer/exhaust piping installation

Project co-funded by European Union Funds (ERDF, IPA)

PROPOSALS OF IMPROVEMENTS – AMADEUS SILVER III

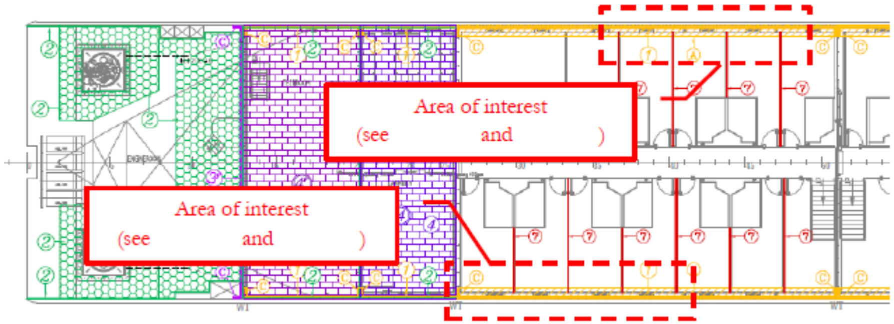


Side shell improvements

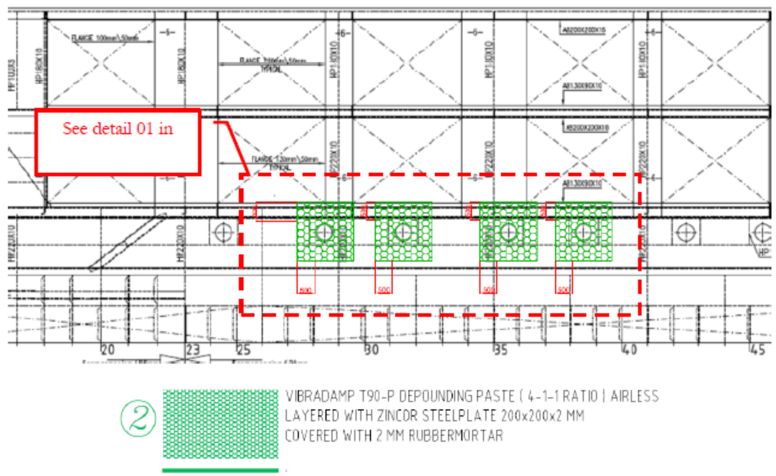


Tank deck improvements

PROPOSALS OF IMPROVEMENTS – AMADEUS SILVER III

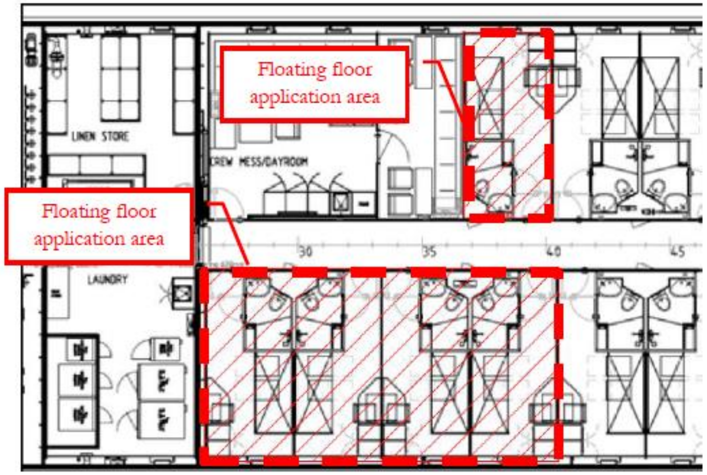


insulation plan improvements

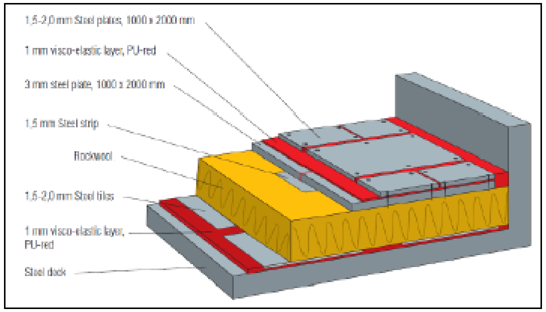


damping treatment improvements

PROPOSALS OF IMPROVEMENTS – AMADEUS SILVER III



floor plan improvements



Detail

OPTION 01 – RECOMMENDATION FOR EXISTING FLEET

The activity has been developed following the below listed phases:
- **Vibro-acoustic measurements on board**: measurements have been performed on Amadeus Diamond, Amadeus Brabant and Amadeus Royal. Noise and vibration measurements have been performed in the crew quarters and on propulsion system machinery.
- **Calibration of the developed vibro-acoustic numerical models** with the data measured on board during the performed river trials.
- **Study of improvements** for vibro-acoustic levels mitigation.
- **Test of the studied improvements** by performing iterative acoustic and FE analysis.
- Evaluation of **achieved benefits** in terms of noise and vibration levels mitigation.

OPTION 01 – NOISE LEVEL AMADEUS ROYAL

Area	Area	Measured dB(A) noise level before improvements	Predicted dB(A) noise level after improvements	Noise levels reduction [dB(A)]
Amadeus Royal	Crew cabin – C1	56.0	55.0	-1.0
	Crew cabin – C2	56.5	55.0	-1.5
	Crew cabin – C3	54.3	53.0	-1.3
	Crew cabin – C4	53.3	52.0	-1.3
	Crew cabin – C5	52.6	52.0	-0.6

Table 24 – Noise levels reduction

Area	Area	DNV-GL comfort class before improvements [CRN1 – CRN2 – CRN3]	DNV-GL comfort class after improvements [CRN1 – CRN2 – CRN3]
Amadeus Royal	Crew cabin – C1	CRN3	CRN2
	Crew cabin – C2	CRN3	CRN2
	Crew cabin – C3	CRN2	CRN2
	Crew cabin – C4	CRN2	CRN2
	Crew cabin – C5	CRN2	CRN2

Table 25 – Comparison between comfort class level before and after improvements

OPTION 01 – NOISE LEVEL AMADEUS DIAMOND

Area	Area	Measured dB(A) noise level before improvements	Predicted dB(A) noise level after improvements	Noise levels reduction [dB(A)]
Amadeus Diamond	Crew cabin – C1	58.2	55.0	-3.2
	Crew cabin – C2	57.5	55.0	-2.5
	Crew cabin – C4	54.4	53.0	-1.4
	Crew cabin – C5	55.4	53.0	-2.4

Table 26 – Noise levels reduction

Area	Area	DNV-GL comfort class before improvements [CRN1 – CRN2 – CRN3]	DNV-GL comfort class after improvements [CRN1 – CRN2 – CRN3]
Amadeus Diamond	Crew cabin – C1	CRN3	CRN2
	Crew cabin – C2	CRN3	CRN2
	Crew cabin – C4	CRN2	CRN2
	Crew cabin – C5	CRN2	CRN2

Table 27 – Comparison between comfort class level before and after improvements

OPTION 01 – NOISE LEVEL AMADEUS BRABANT

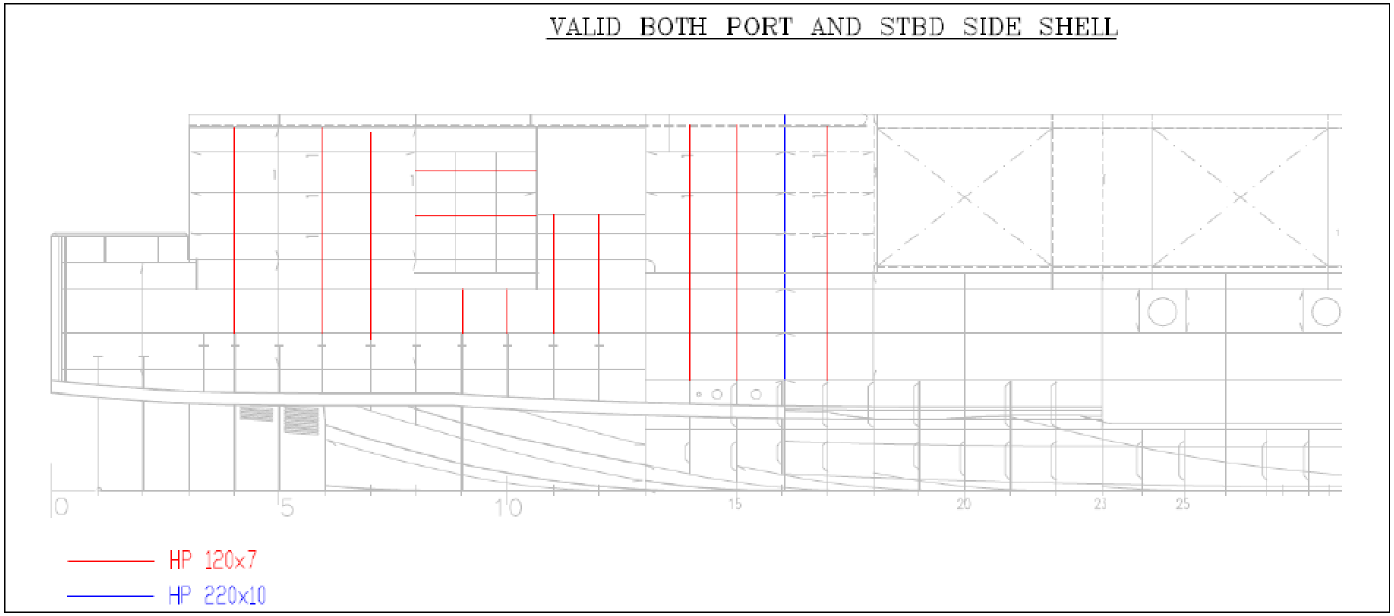
Area	Area	Measured dB(A) noise level before improvements	Predicted dB(A) noise level after improvements	Noise levels reduction [dB(A)]
Amadeus Brabant	Crew cabin – C1	59.4	55.4	-4.4
	Crew cabin – C2	59.1	54.7	-4.3
	Crew cabin – C3	58.5	54.7	-3.8
	Crew cabin – C4	55.7	53.0	-2.7
	Crew cabin – C5	50.1	49.0	-1.1

Table 28 – Noise levels reduction

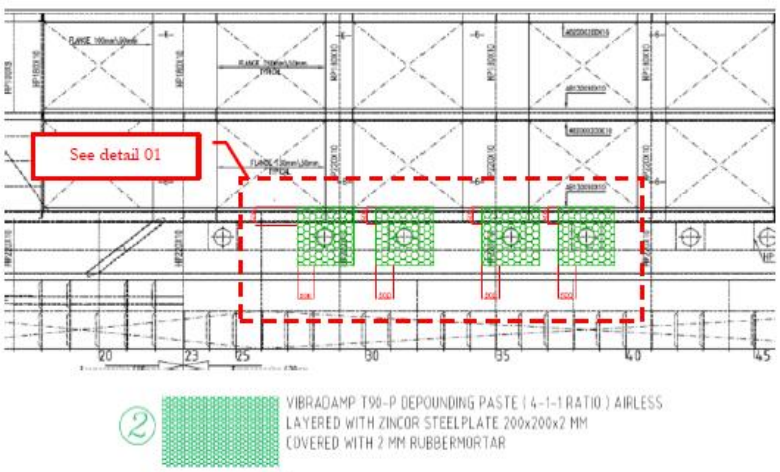
Area	Area	DNV-GL comfort class before improvements [CRN1 – CRN2 – CRN3]	DNV-GL comfort class after improvements [CRN1 – CRN2 – CRN3]
Amadeus Brabant	Crew cabin – C1	CRN3	CRN3
	Crew cabin – C2	CRN3	CRN2
	Crew cabin – C3	CRN3	CRN2
	Crew cabin – C4	CRN3	CRN2
	Crew cabin – C5	CRN2	CRN2

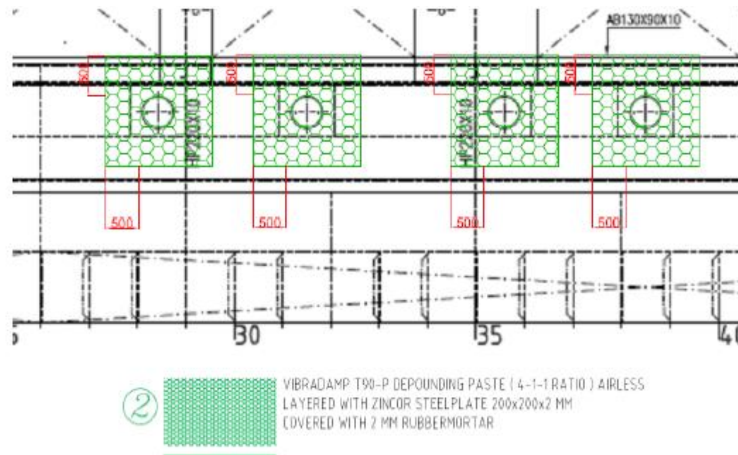
Table 29 – Comparison between comfort class level before and after improvements

OPTION 01 - PROPOSALS OF IMPROVEMENTS
AMADEUS ROYAL

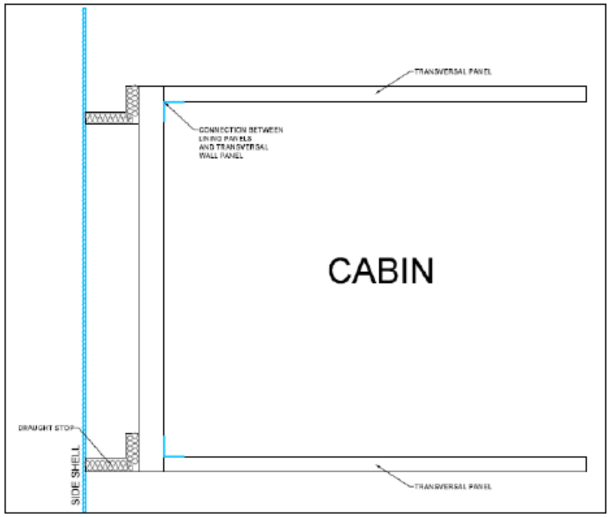


OPTION 01 - PROPOSALS OF IMPROVEMENTS
AMADEUS ROYAL

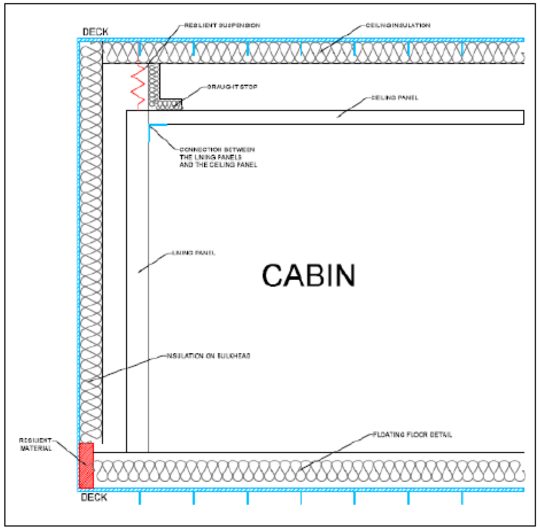




OPTION 01 - PROPOSALS OF IMPROVEMENTS AMADEUS ROYAL

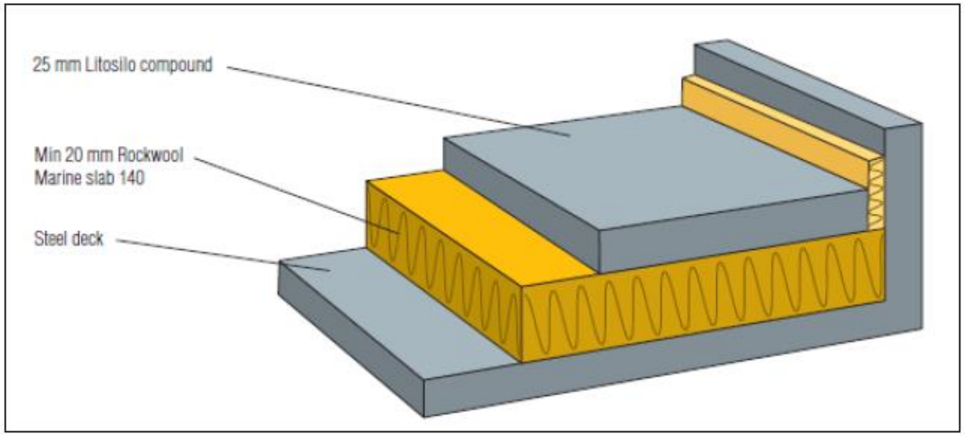


Proposed acoustic barrier preventing, wall detail



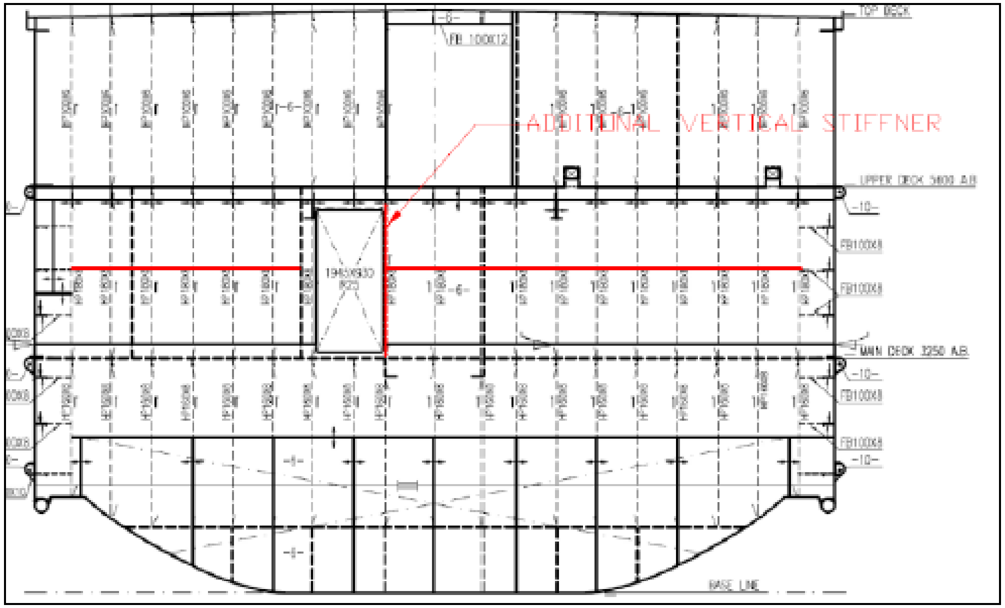
Proposed acoustic barrier preventing, floor and ceiling details

OPTION 01 - PROPOSALS OF IMPROVEMENTS AMADEUS ROYAL



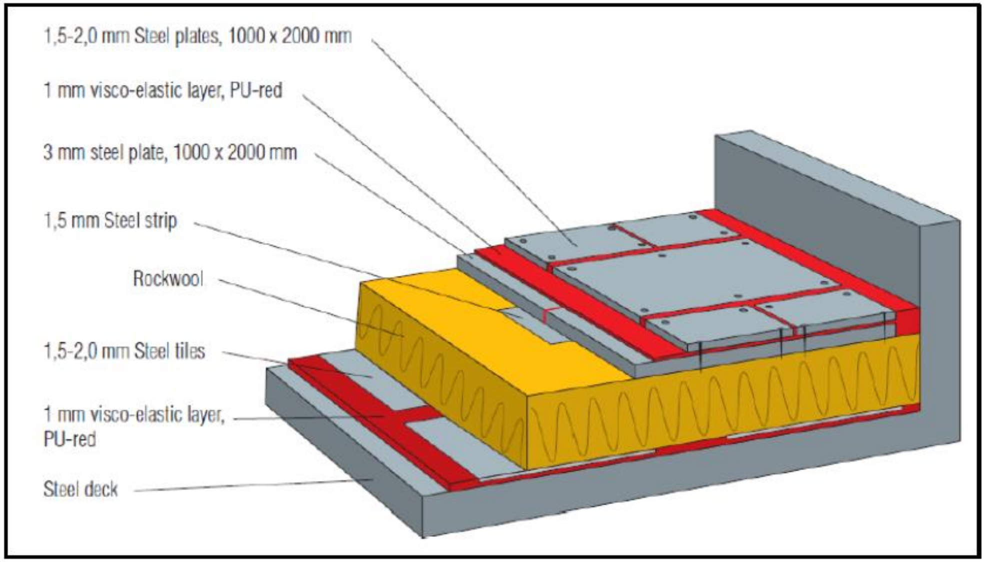
Proposed floating floor typology

OPTION 01 - PROPOSALS OF IMPROVEMENTS
AMADEUS DIAMOND



Detail of the structural improvements

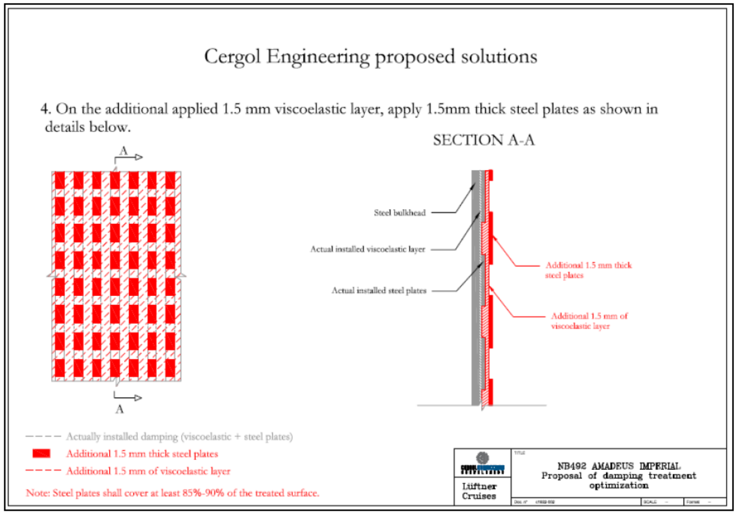
OPTION 01 - PROPOSALS OF IMPROVEMENTS AMADEUS DIAMOND



Proposed floating floor typology

OPTION 02 – GUIDELINES FOR YARD IN DESIGN PROCESS

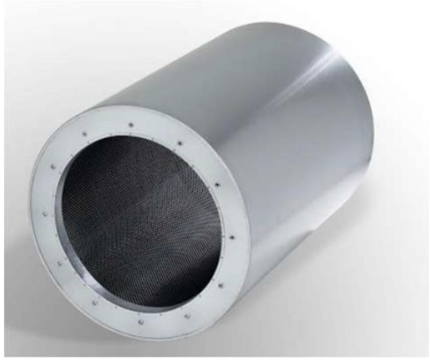
Abstract from developed technical report after survey performed on board, proposals for damping treatment optimization



Abstract from developed technical report after survey performed on board, proposals for damping treatment optimization

OPTION 03 – REDUCTION OF EXTERNAL NOISE

In the cities where the shore connection is required, the main external noise sources become the HVAC system extraction outlets, due to the ventilation fans.
In these cases, it is suggested to install adequate silencers, i.e. with a high TL in order to minimize the noise at the ventilation extraction grilles.



Typical cylindrical silencer

NOISE LEVELS MEASUREMENTS RESULTS AFTER INSTALLATION OF PROPOSED IMPROVEMENTS

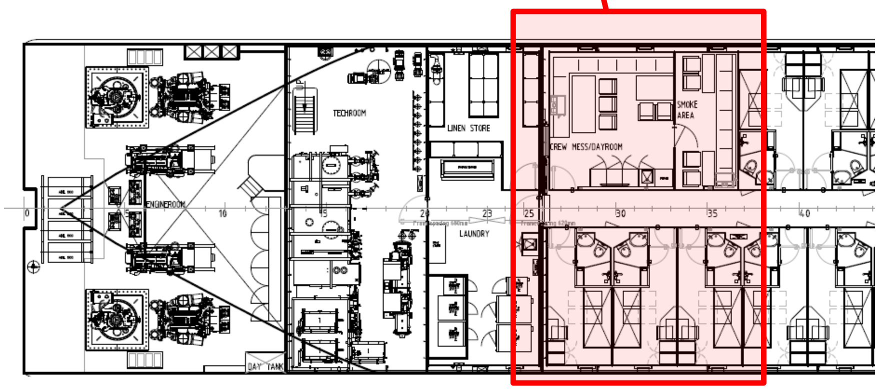
NOISE LEVELS MEASUREMENTS RESULTS AFTER INSTALLATION OF PROPOSED IMPROVEMENTS

The next new building, has been delivered in 2020.
On this vessel, the proposed vibro-acoustic mitigation measures have been implemented.
The results of the performed noise levels measurement campaign (performed by <u>third party</u>) and a summary of the achieved noise levels mitigation (comparison analysis with older sister ships noise levels) are shown in the following pages.

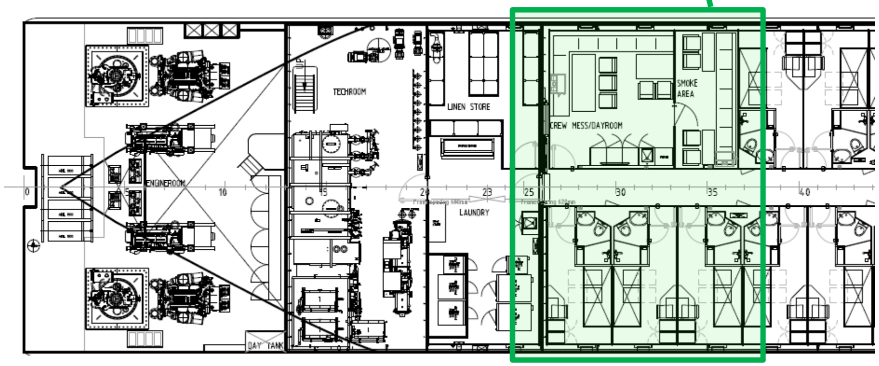
NOISE LEVELS MEASUREMENTS RESULTS
AFTER INSTALLATION OF PROPOSED IMPROVEMENTS

Average measured noise level: 58 dBA

Average measured noise level: 56 dBA



Reference sister ship

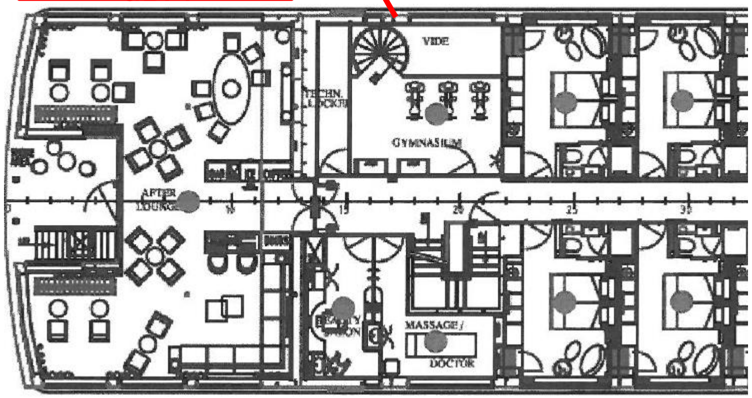


Next new building

CREW CABINS ON LOWER DECK

NOISE LEVELS MEASUREMENTS RESULTS AFTER INSTALLATION OF PROPOSED IMPROVEMENTS

Average measured noise level: 55 dBA



Reference sister ship

Average measured noise level: 53 dBA

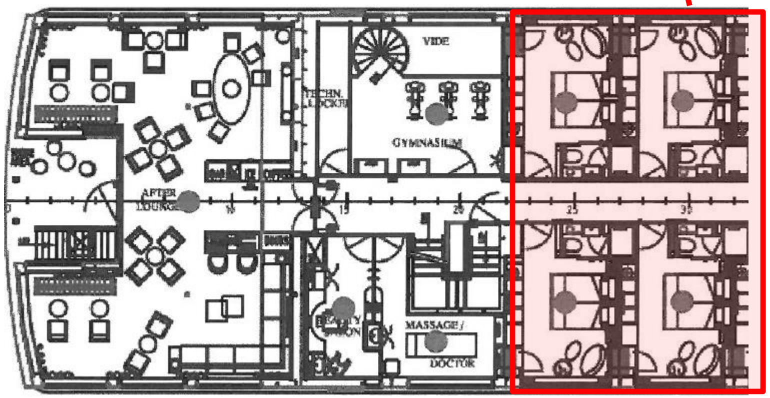
Next new building

PASSENGER CABINS ON UPPER DECK

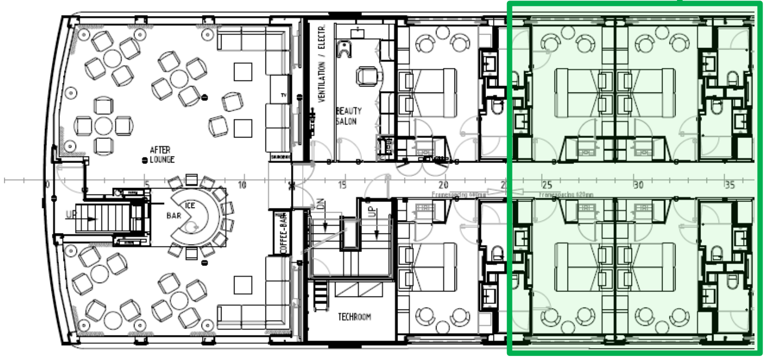
NOISE LEVELS MEASUREMENTS RESULTS AFTER INSTALLATION OF PROPOSED IMPROVEMENTS

Average measured noise level: 51 dBA

Average measured noise level: 50 dBA



Sister ship

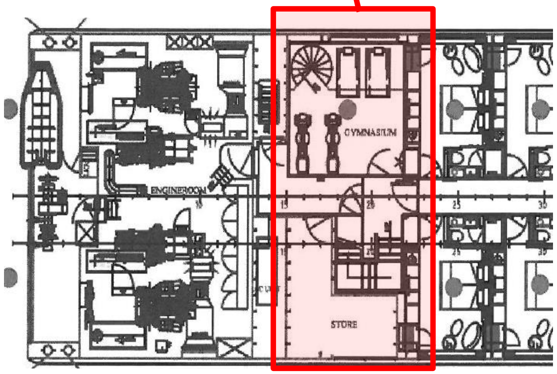


Next new building

PASSENGER CABINS ON UPPER DECK

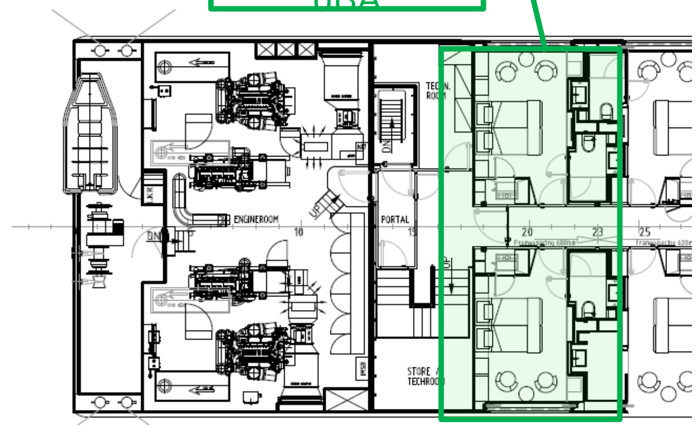
NOISE LEVELS MEASUREMENTS RESULTS
AFTER INSTALLATION OF PROPOSED IMPROVEMENTS

Average measured noise level: 55 dBA



Reference sister ship

Average measured noise level: 54 dBA



Next new building

PASSENGER CABINS ON MAIN DECK

NOISE LEVELS MEASUREMENTS RESULTS AFTER INSTALLATION OF PROPOSED IMPROVEMENTS

CONCLUSIONS:

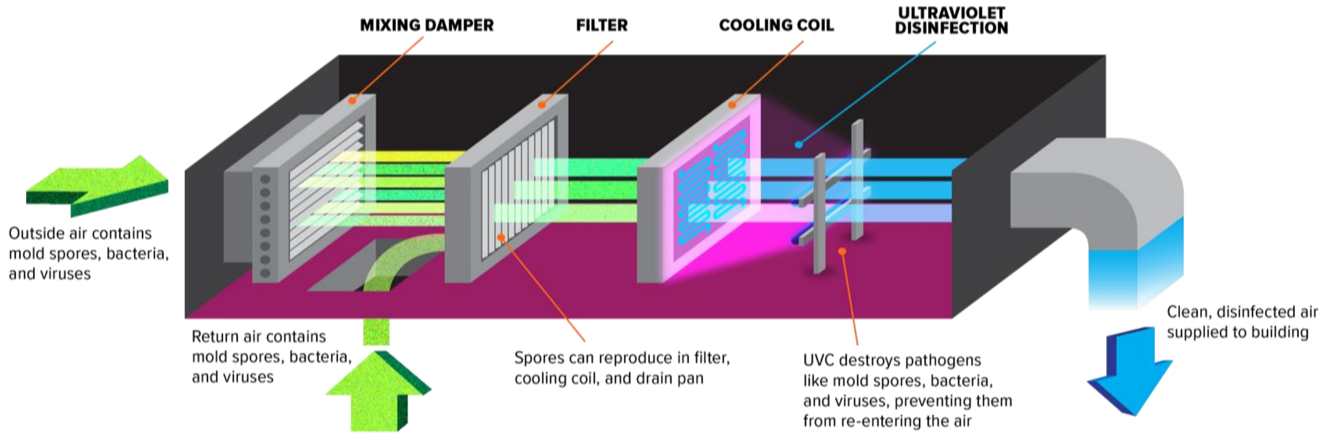
FOR THE CREW ACCOMMODATION AREAS, AN AVERAGE REDUCTION OF 2 DBA HAS BEEN ACHIEVED.

ALSO FOR THE PASSENGER CABINS, THE ACHIEVED NOISE REDUCTION CAN BE CONSIDERED SATISFACTORY.

Saving lives & saving energy :
Germicidal UV HVAC and Smart Monitoring

In many cases, UV lights will help keep the ship's HVAC system cleaner and require less maintenance.

A clean system that runs efficiently can also end up saving you money on energy costs, say US experts. UV lights can restore heat transfer and net cooling capacity, saving energy costs.

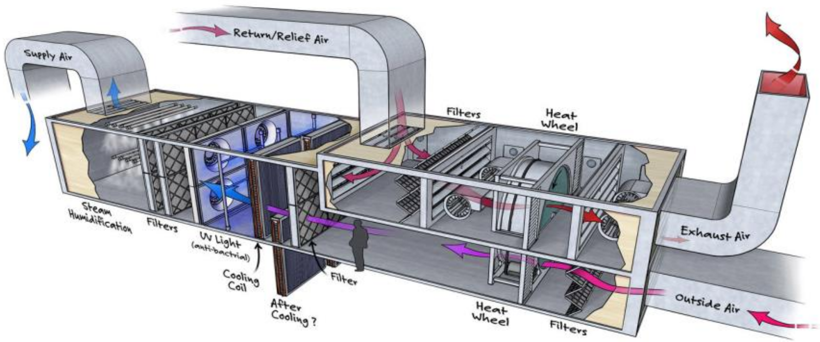


In many cases, UV lights will help keep the ship's HVAC system cleaner and require less maintenance.

Engineering Health Controls :
Germicidal UV HVAC and Smart Monitoring

In many cases, UV lights will help keep the ship's HVAC system cleaner and require less maintenance.

A clean system that runs efficiently can also end up saving you money on energy costs, say US experts. UV lights can restore heat transfer and net cooling capacity, saving energy costs.



Other pandemic precautionary measures

- Surface treatment systems
- Smart fever detection system
- Social distancing by design

Project co-funded by European Union Funds (ERDF, IPA)

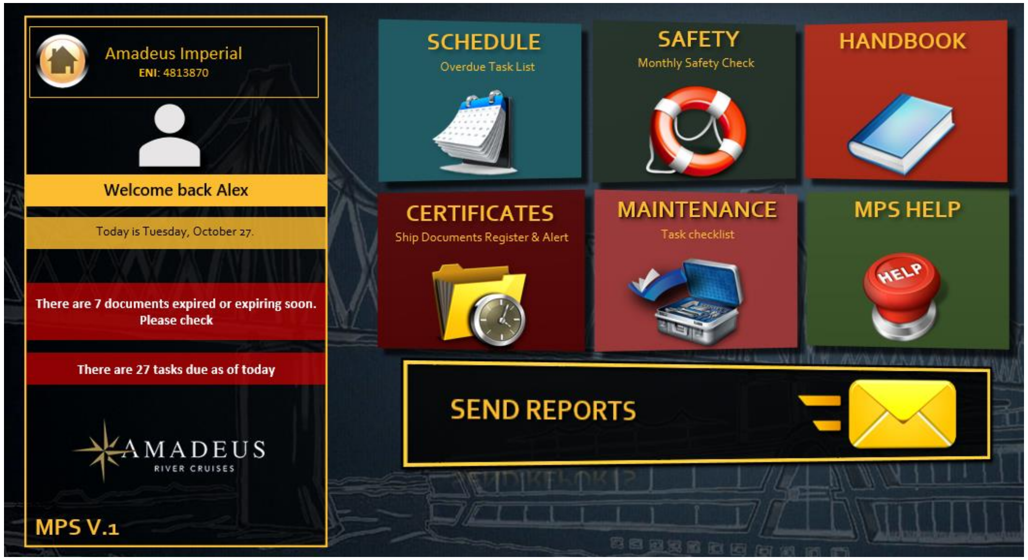
Comply with and improve quality, health, safety and environmental regulations by digitalizing “non-digital crew”

Safety, fuel economy, and eco-efficiency are core challenges for today’s ship owners, operators and the European Union. Optimizing ship efficiency and minimizing risks during warm lay-ups and operation can make the difference.

The challenge is that, whilst the tools exist for sea going cruise ships, there is no tailor-made software program available for the inland cruise industry.

Raise awareness and expose the hidden value in operational data to drive performance and improve efficiency by providing easy to use digital tools to the onboard personnel.

- Reduce fuel consumption, therefore environmental impact
- Reduce manpower allocated to layup harbor, therefore health risks and energy consumption
- Facilitate planning and execution of all regulatory compliance activities and maintenance tasks
- Replication to enable real-time visibility to every vessel, as well as the entire fleet.



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Danube Transnational Programme
GRENDEL

Radu Comanici
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GRENDEL "Green and efficient Danube fleet"

Towards modernisation & greening of Danube inland waterborne sector and strengthening its competitiveness

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