A PROTOTYPE THERMAL TREATMENT FOR FOULED INTERNAL PIPEWORK OF YACHTS

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BIOFOULING SOLUTIONS

NIWA
Taihoro Nukurangi

Ministry for Primary Industries
Manatū Ahu Matua

MPI OPERATIONAL RESEARCH PROJECT 405135

- To provide a protocol for a practical, feasible and efficacious tool for use on all arriving recreational vessels including non-compliant vessels

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APPROACH

Review pipework configurations, risks, and treatment options

↓

Select a treatment agent

↓

Design and build a treatment system

↓

Optimise the treatment system in the laboratory

↓

Validate the treatment system in the field

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PIPEWORK CONFIGURATIONS

- Three main classes of system relevant to biosecurity:
    1. Engine-cooling
    2. Ancillary seawater supply (galley, heads, air-conditioning, refrigeration, desalination)
    3. Below water discharge (black-water, deck-draining)
- Considerable variety of configurations and sizes

BIOFOULING RISK

- Barnacles, hydroids, mussels, oysters, and tubeworms
- Typically low abundance but notable exceptions
- Concentrated near inlets or outlets
- Absent where no seawater exchange
- Lack of data

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TREATMENT AGENT SELECTION

Treatment category	Treatment agent	Effective	Safe*	Biosecure	Consenting	Compatibile*	Feasibile	Quality control
Chemical treatment agents	Chlorine	?	✓	✓	✓	✓	✓	✓
	Chlorine dioxide	?	?	✓	✗	✓	✗	✗
	Bromine	?	✓	✓	✗	✓	✓	✓
	Hydrogen peroxide	?	✓	✓	✗	✓	✓	✓
	Ferrate	?	✓	✓	✗	✓	✗	✗
	Peracetic acid	?	✓	✓	✗	✓	✓	✓
	Acetic acid	?	✓	✓	✓	✓	✓	✓
	Descaler formulation – Rydlyme®	✓	?	✓	✗	✓	✓	?
	Quaternary ammonium compounds	?	✗	✓	✗	✓	✓	?
Non-chemical treatment agents	Physical removal	✗	✓	?	✓	✓	✗	✗
	Thermal stress	✓	✓	✓	✓	✓	✓	✓
	Deoxygenation	✗	✓	✓	✓	✓	✓	✓
	Osmotic shock	✗	✓	✓	✓	✓	✓	✓

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DESIGNING A HEAT TREATMENT SYSTEM

Description	Experimental design	Test organisms	Thermal tolerance	Reference
Laboratory and mock sea chest experiments using heated seawater to kill a range of temperate biofouling organisms.	Small (10 – 30 mm) and large (55 – 80 mm) mussels (*Perna canaliculus* and *Mytilus galloprovincialis*) exposed to 35, 37.5, 40, 42.5, 45, or 50 °C for 5, 10, 20, 30, 45 or 60 min (n = 5).	Small *P. canaliculus* Large *P. canaliculus*	100% mortality at 40°C for ≥ 5 min or 37.5°C for ≥ 20 min	Piola and Hopkins (2012)
		Small *M. galloprovincialis* Large *M. galloprovincialis*	100% mortality at 45°C for ≥ 5 min or 40°C for ≥ 20 min	
	Hydroids, solitary and colonial ascidians, bryozoans, anemones, shrimp, oysters, gastropods, barnacles, isopods, and sea stars exposed to 37.5, 40, 42.5, or 60°C for 60, 30, 20, or 30 min, respectively (n = 5)	*Crassostrea gigas*	100% mortality at 60°C for 30 min, or 57.5°C for 60 min	
		Elminus modestus	100% mortality at 42.5°C for 30 min	
		Bougainvillea muscus *Ciona* spp. *Botrylloides leachi* *Didemnum vexillum* *Bugula neritina* *Actinothoe albocincta* *Palaemon affinis* *Melagraphia aethiops* *Austrominius modestus* *Epopella plicata* *Natatolana pellucida* *Stichaster australis* *Patiriella regularis* *Coscinasterias calama*		
Field trials using a patent heat application system to kill intact biofouling communities on fouled panels and in a mock sea chest.	Fouled plates submerged in seawater heated to 30, 40, 60, or 70°C for 15 or 30 min (n = 4) – survivorship assessed after 12 h.	Bryozoa spp. Polychaeta spp. Cirripedia spp. Bivalvia spp. Ascidiacea spp. Porifira spp.	100% mortality at ≥ 40°C for 15 or 30 min	
	Mock sea chest treated at: 70°C for 10 min; 60°C for 10 min; 40°C for 15 min; and 40°C for 30 min (n = 1).	*Mytilus edulis* *Trichomya hirusta*	100% mortality at 60°C or 70°C for 10 min	Leach (2011)
		Bryozoa spp. Polychaeta spp. Cirripedia spp. Bivalvia spp. Ascidiacea spp. Porifira spp.	100% mortality in all treatments	

60 °C for 1 hour = treatment buffer

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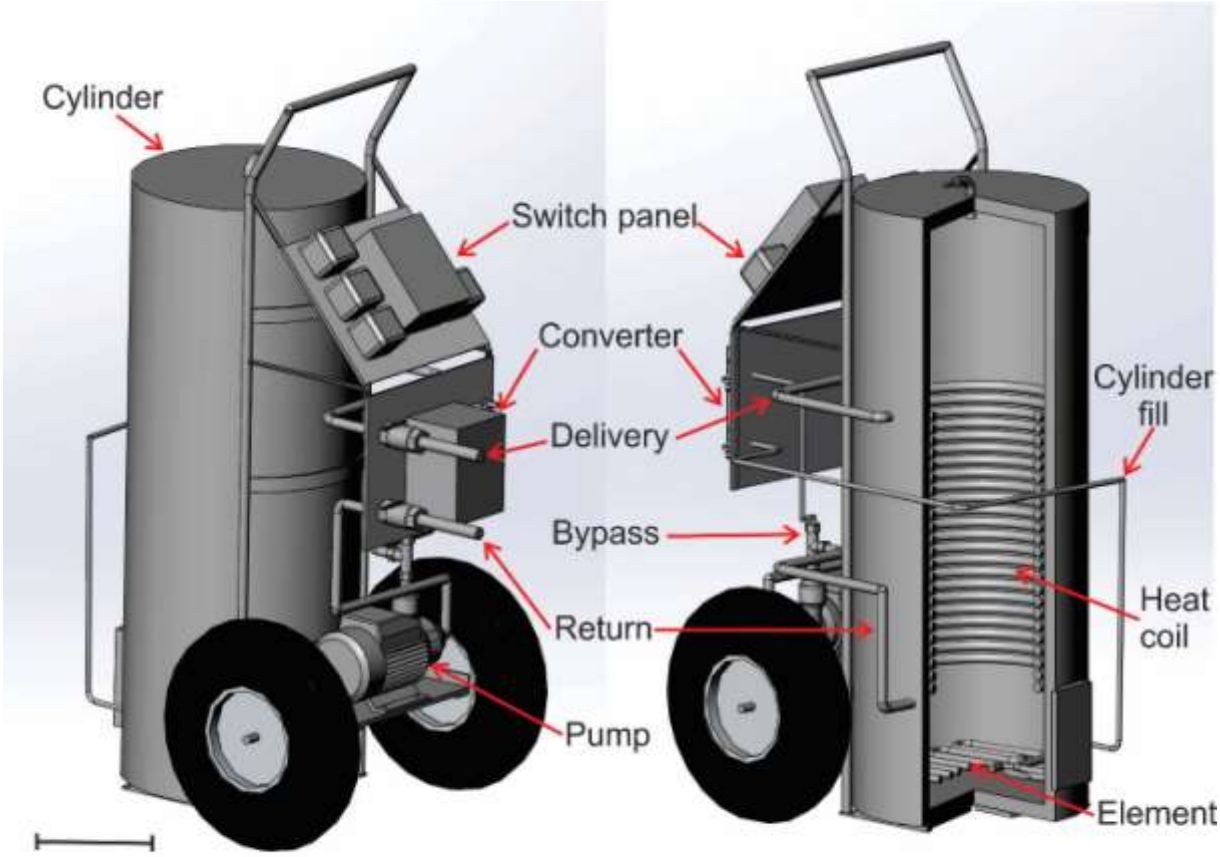
Califont
Recirculator
for
Yacht
Pipework
Treatment



- Based on ‘fluid-califont’
- High degree of control over temperature with low risk of overheating
- Actively circulating seawater to maximise thermal dissipation

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CALIFONT RECIRCULATOR FOR YACHT PIPEWORK TREATMENT

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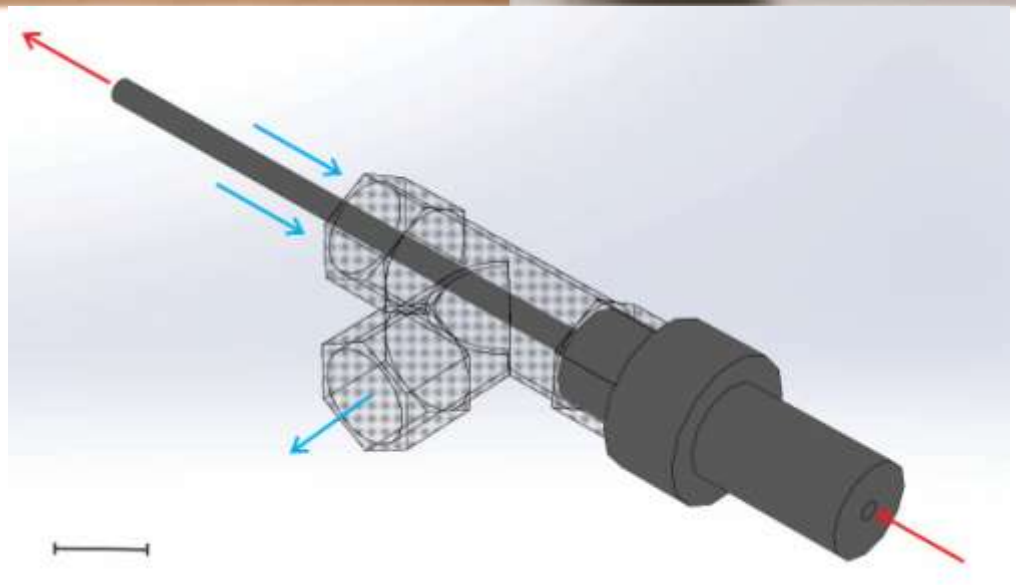
CALIFONT RECIRCULATOR FOR YACHT PIPEWORK TREATMENT



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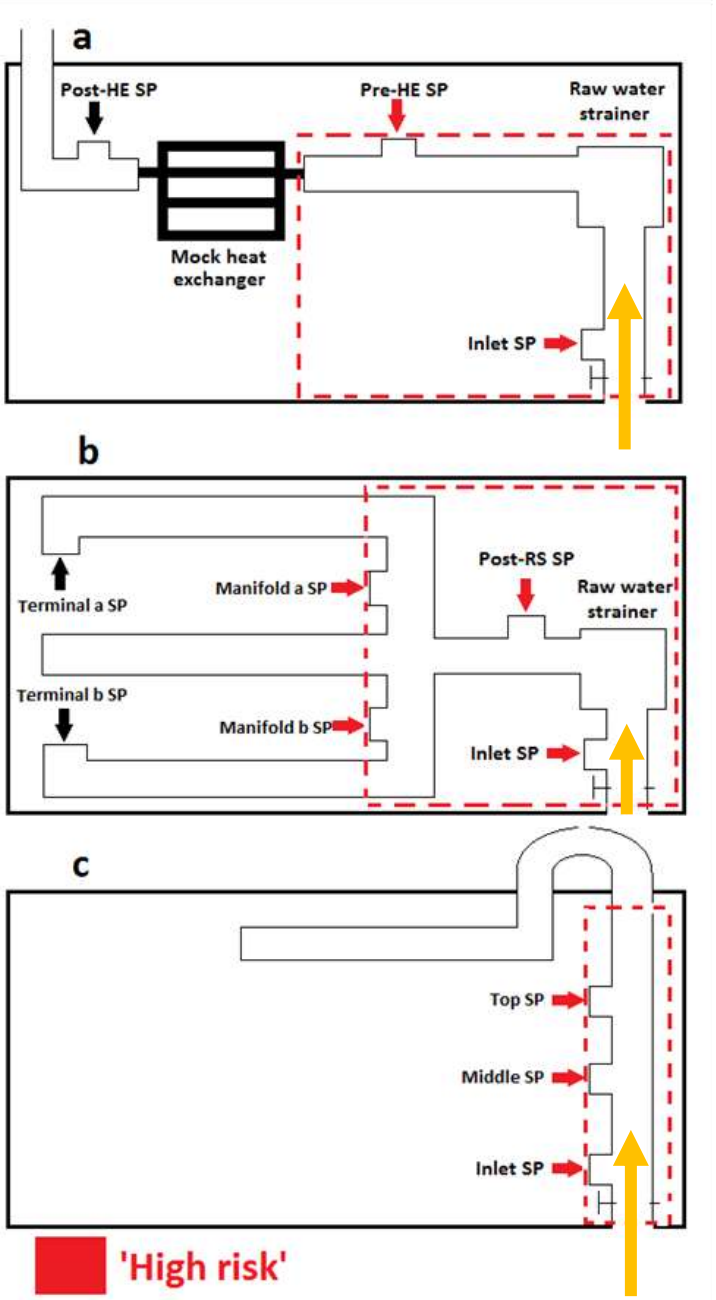
MOCK PIPEWORK SYSTEMS

- Replicate systems
  - a) Engine-cooling,
  - b) Ancillary seawater supply
  - c) Below-water discharge

- Optimise CRYPT to
  - ➢ effectively heat high-risk areas
  - ➢ achieve 100% mortality of *Magallana gigas* (sentinel taxon)



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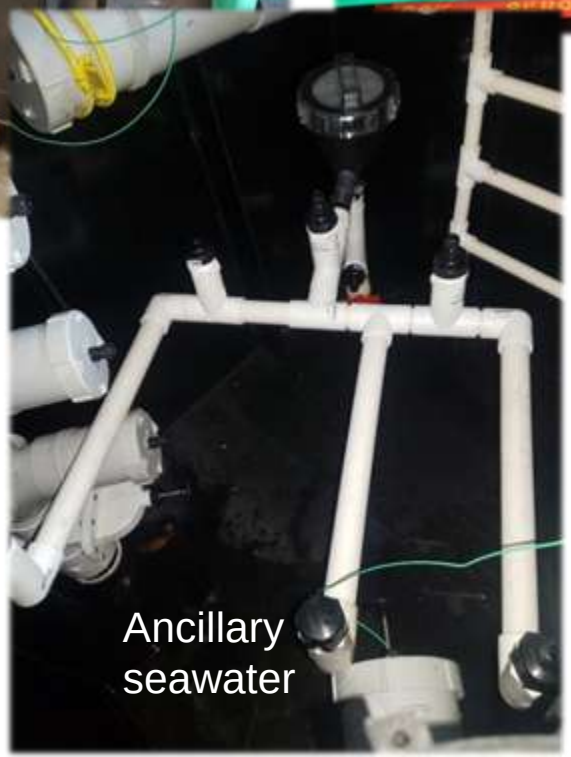
MOCK PIPEWORK SYSTEMS



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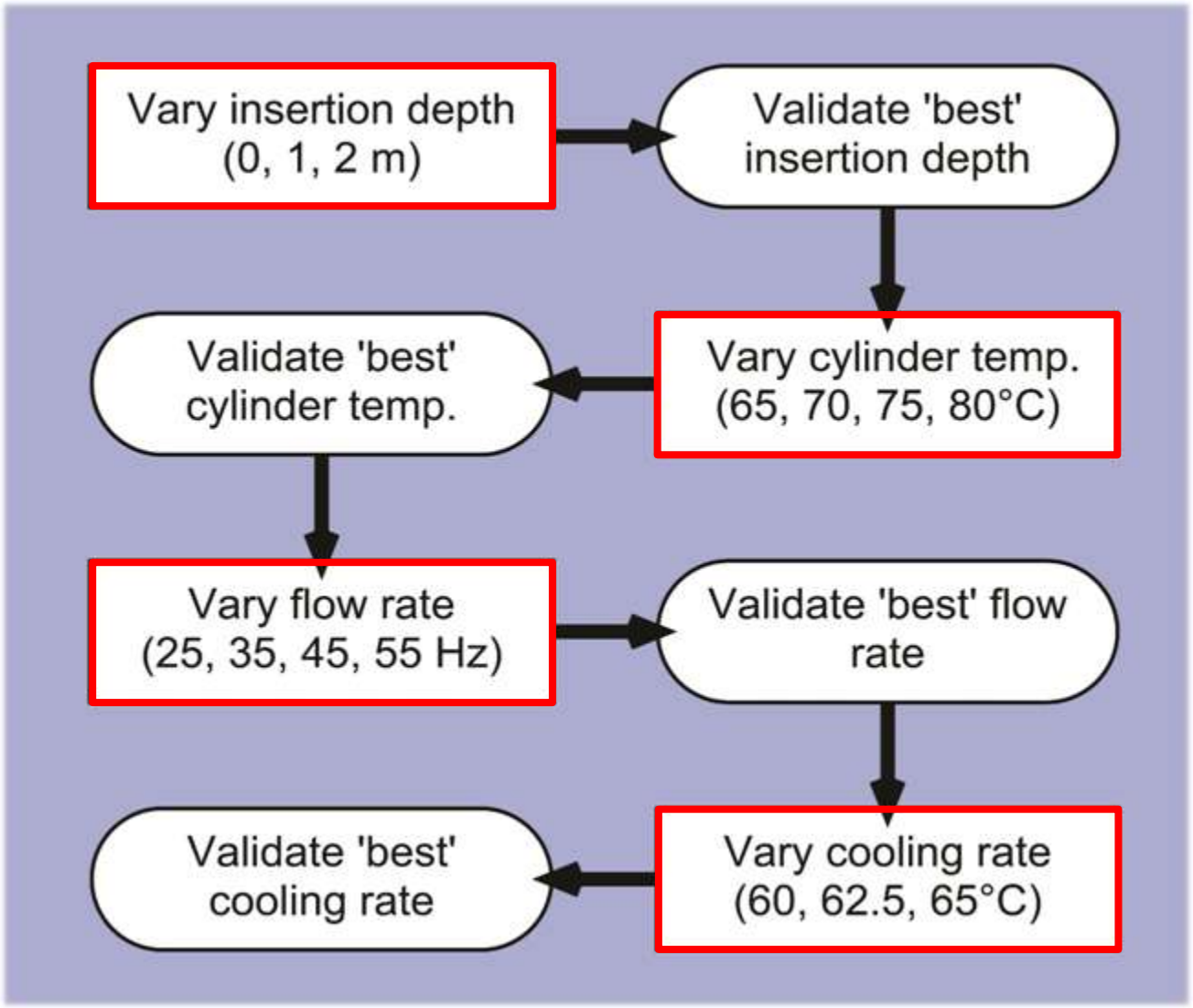
TREATMENT VALIDATION – 4 KEY PARAMETERS



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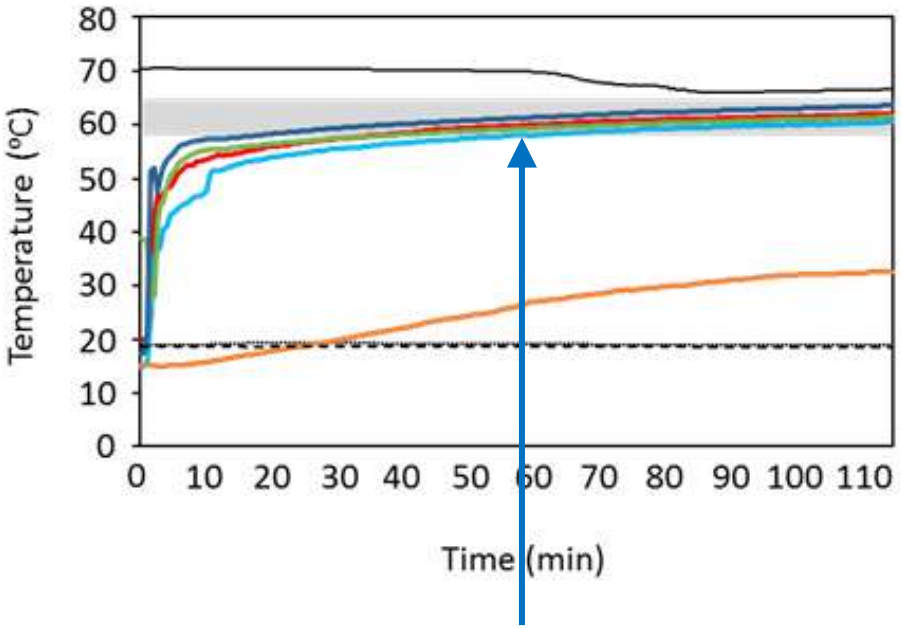
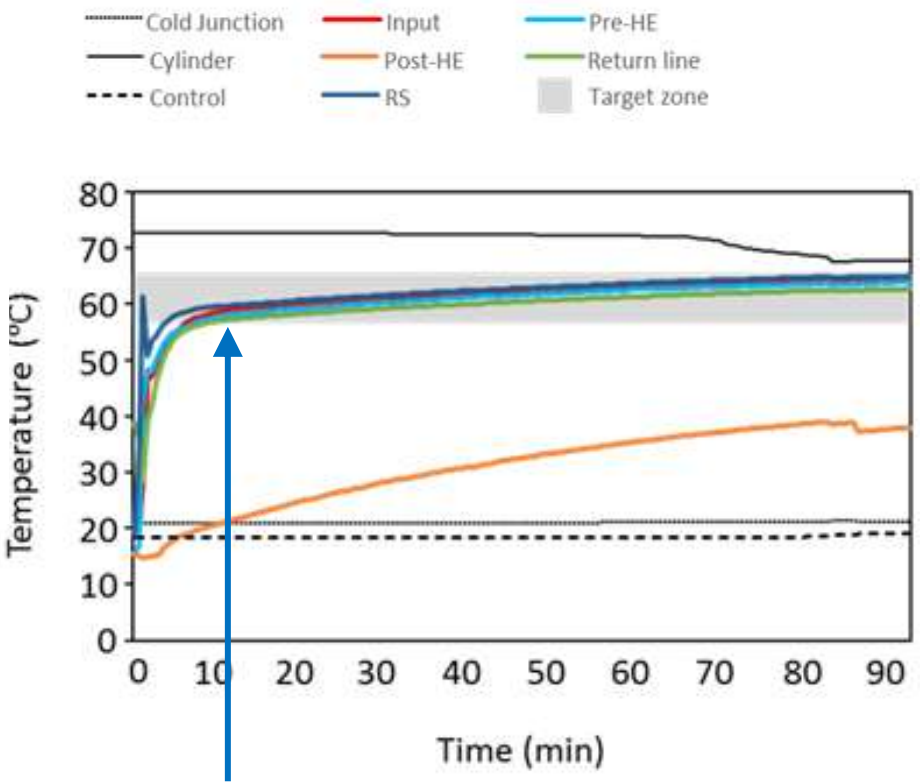
THE OPTIMAL PARAMETERS ARE…..

- Insertion to the first bend in the system
- Cylinder thermostat set to 72.5 °C
- Main pump flow rate set to 20 L min^{-1}



Lethal temperature at high-risk zone after 60 min



Lethal temperature at high-risk zone after 12 min

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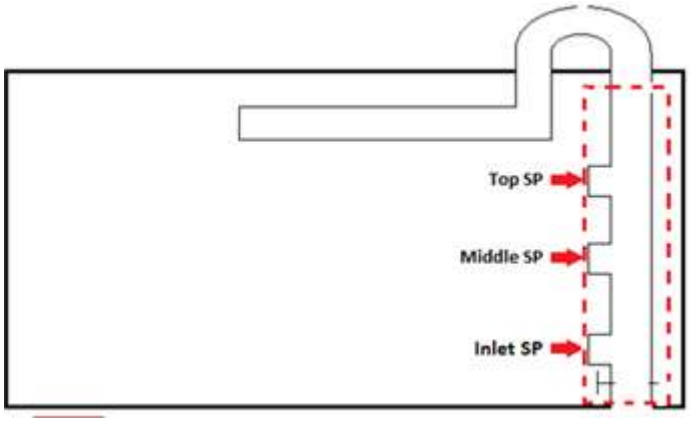
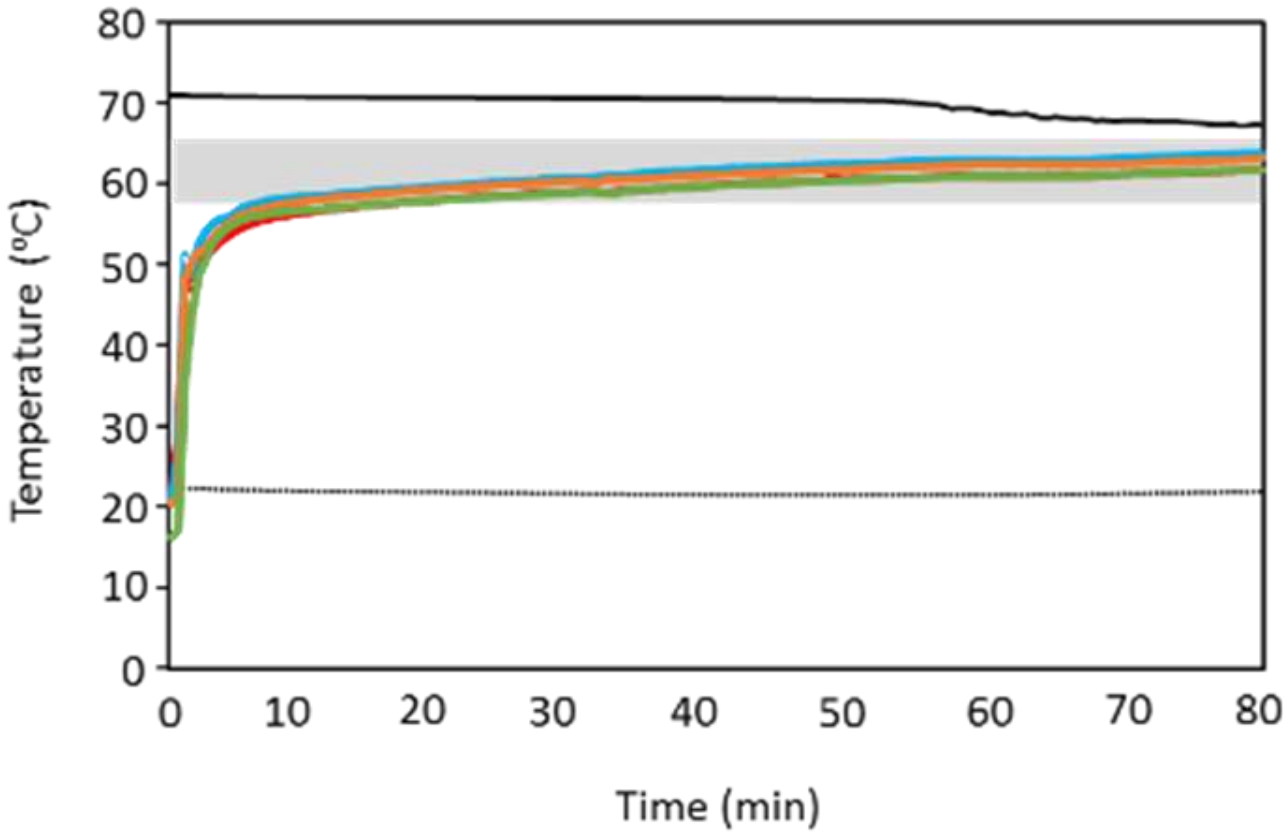
BELOW-WATER DISCHARGE





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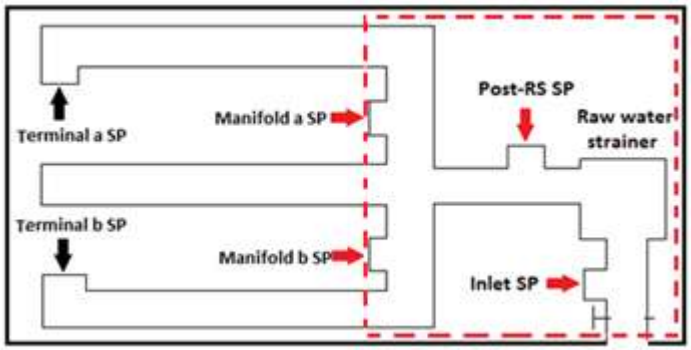
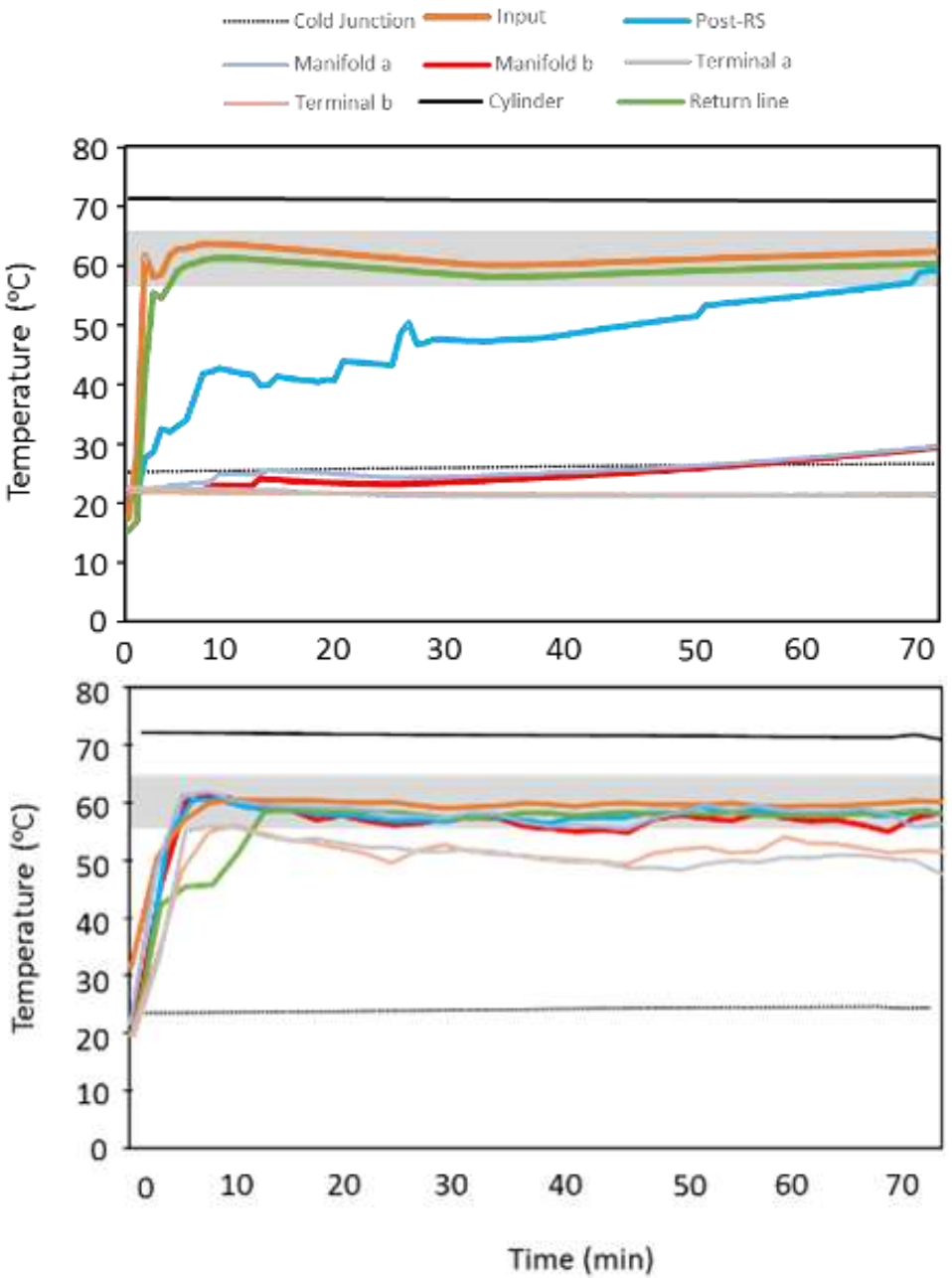
ANCILLARY SEAWATER SUPPLY





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MORTALITY OF ‘SENTINEL OYSTERS….

was always 100% when the prescribed treatment conditions were met

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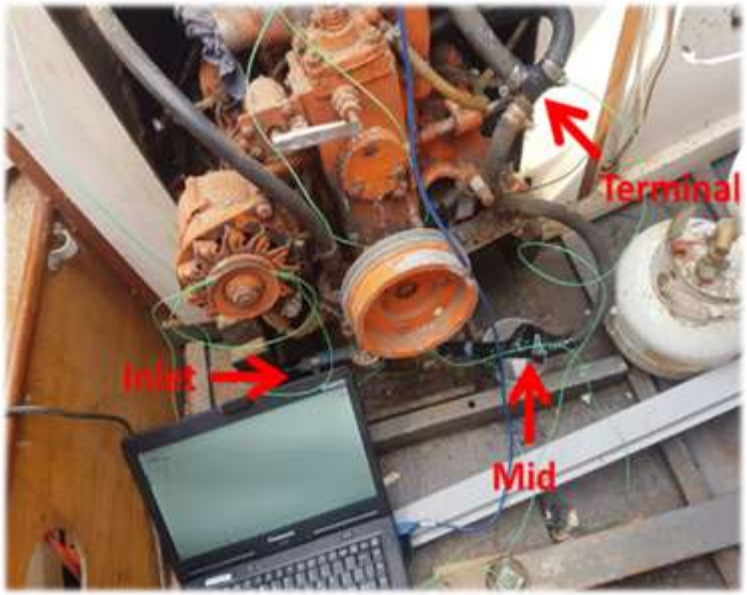
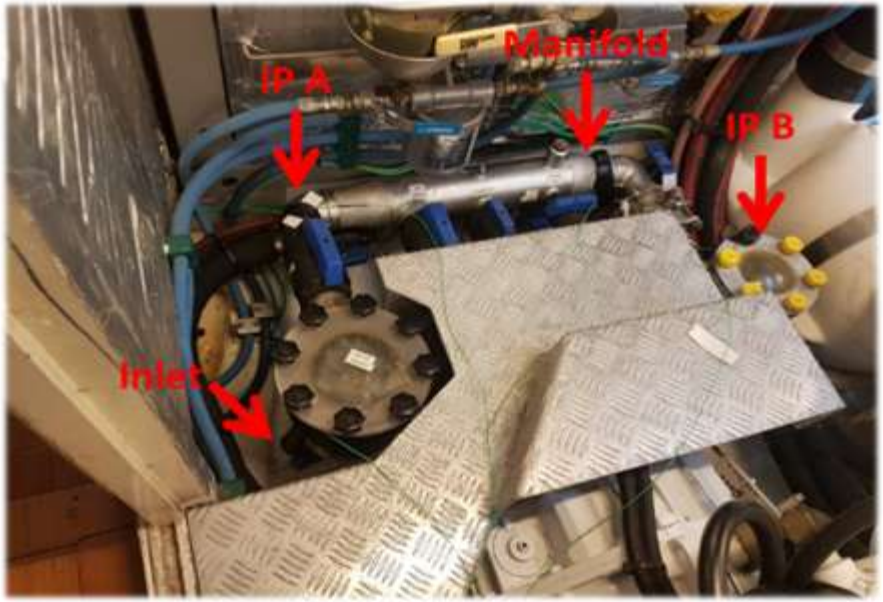
FIELD TESTING

FIELD TESTING





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FIELD TESTING

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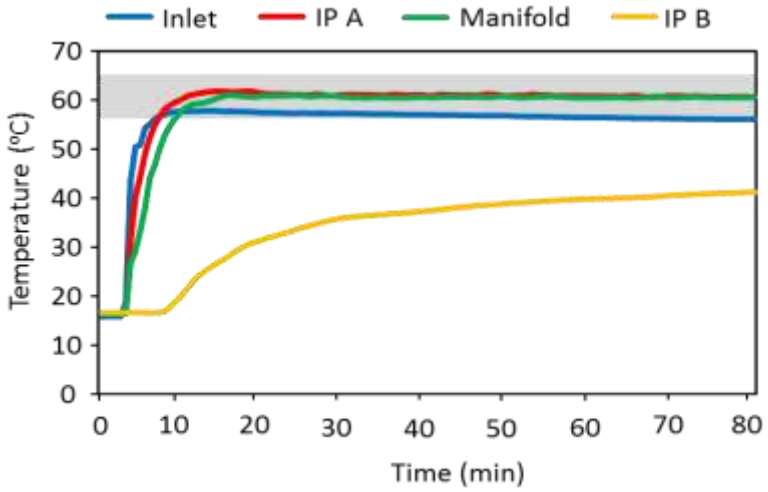
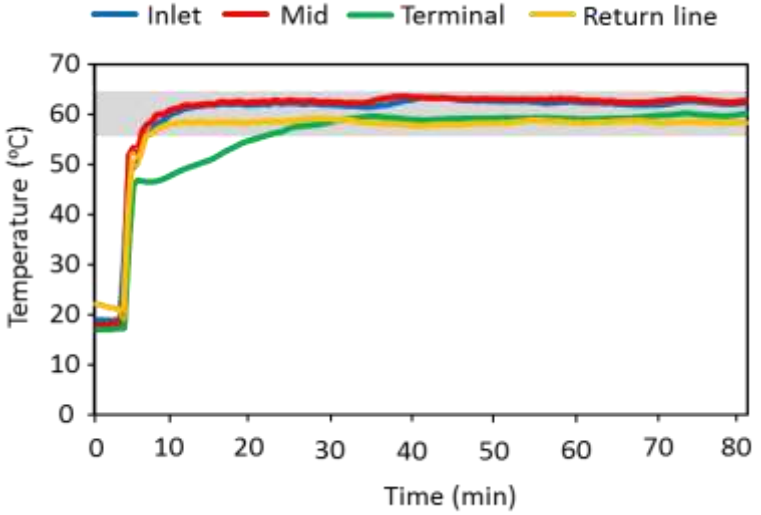
FIELD TESTING – THE GOOD

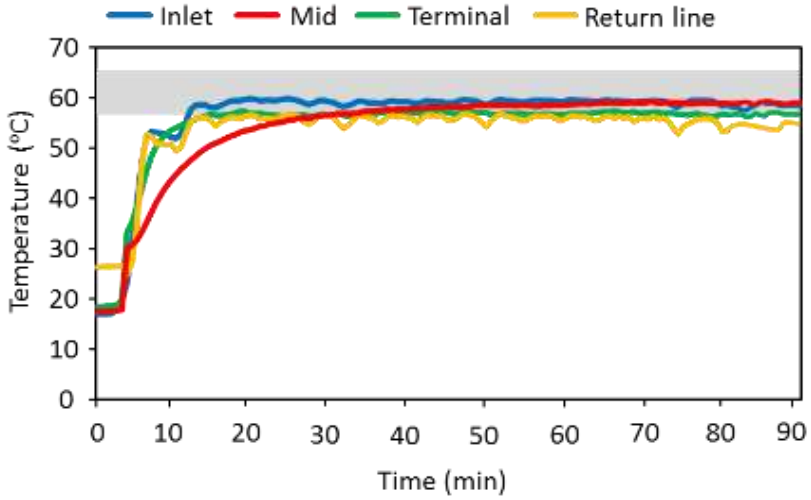
Engine cooling (Vessel A)



Sink and toilet BWD (Vessel C)



ASWS (Vessel E)



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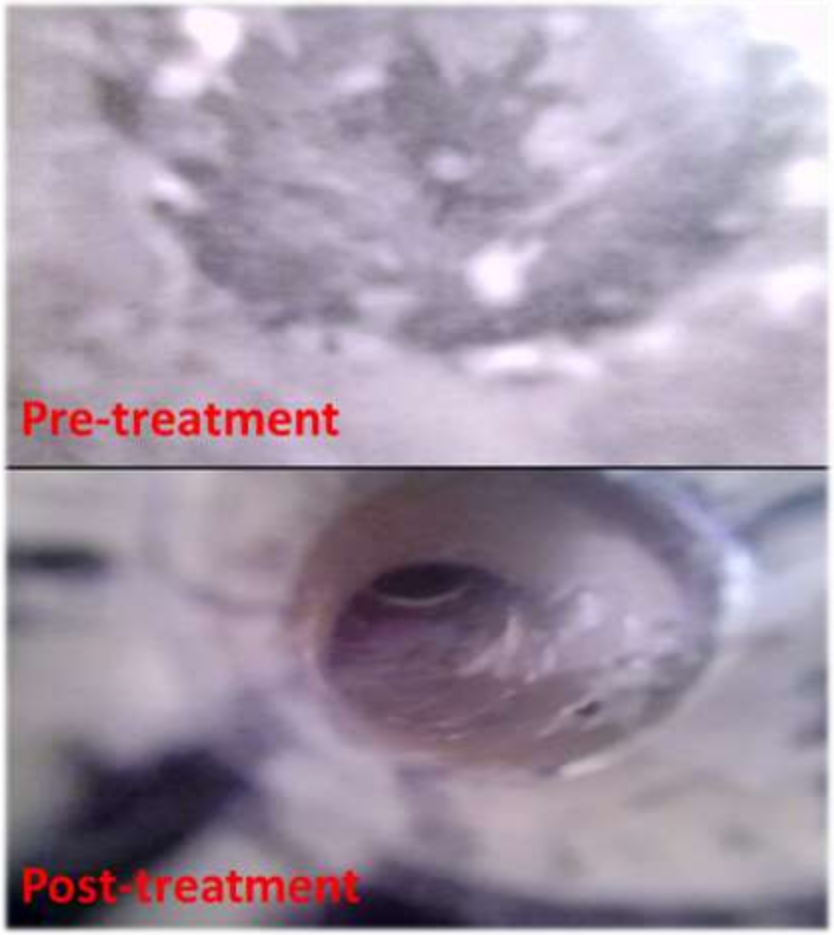
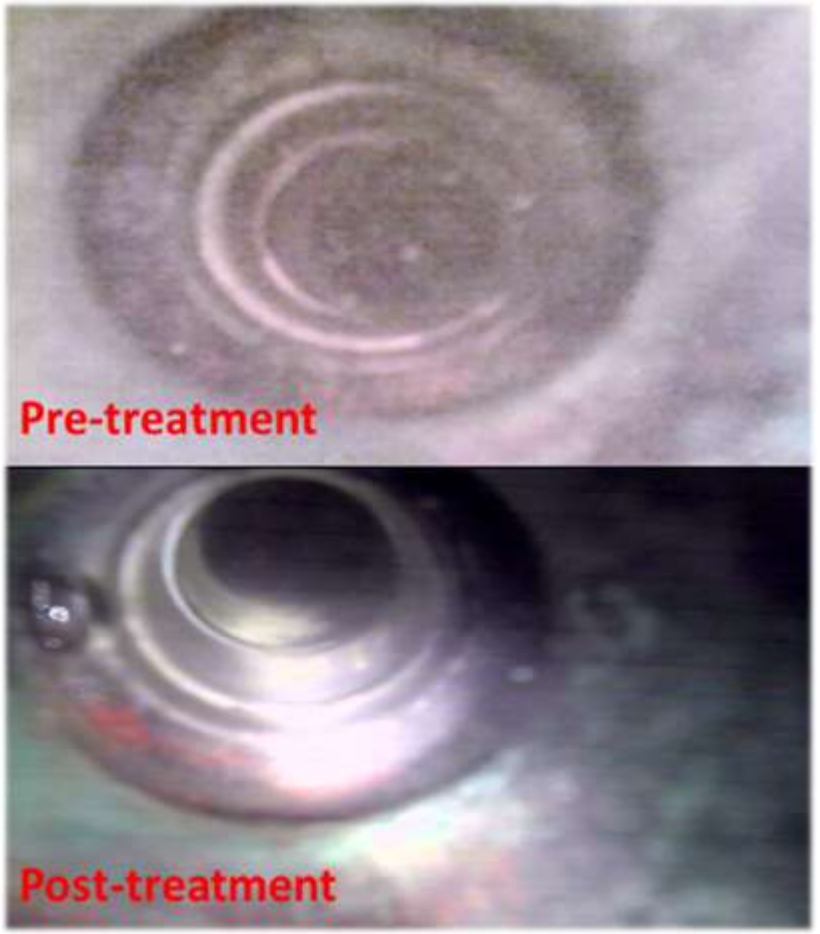
FIELD TESTING – THE GOOD





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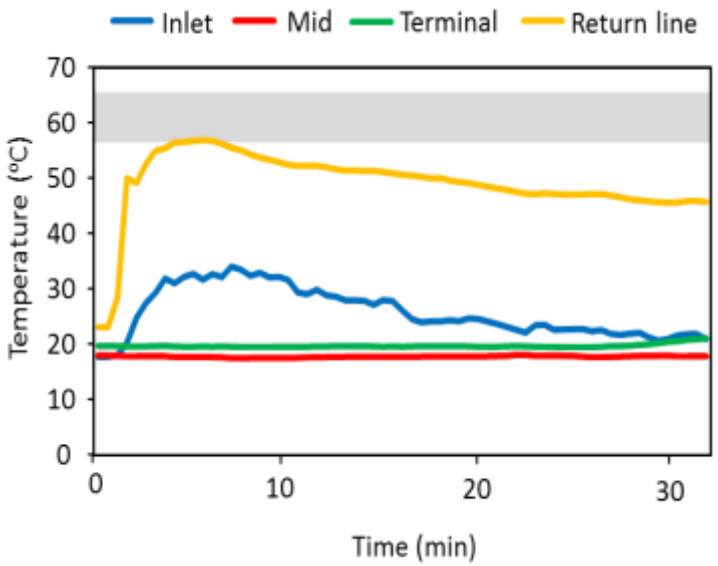
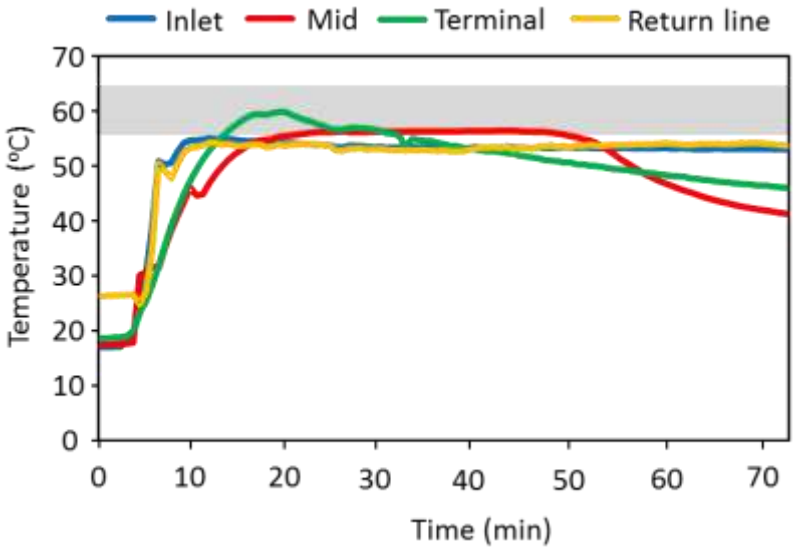
FIELD TESTING – THE CHALLENGES

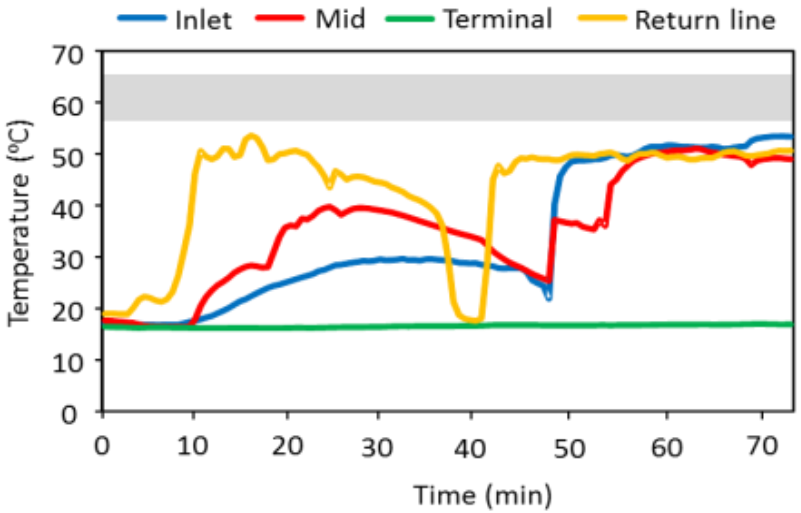
Engine cooling (Vessel B)



Toilet BWD(Vessel D)



ASWS (Vessel B)



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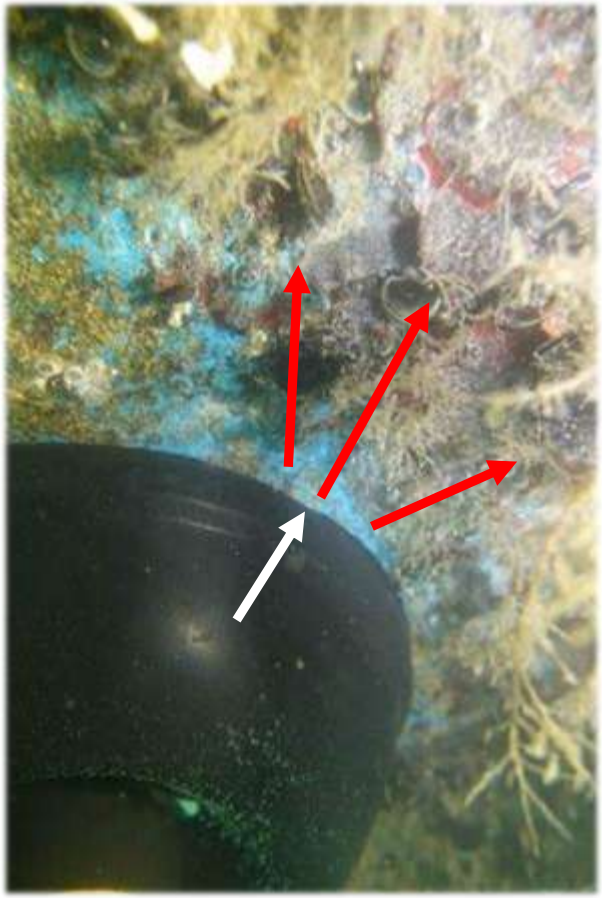
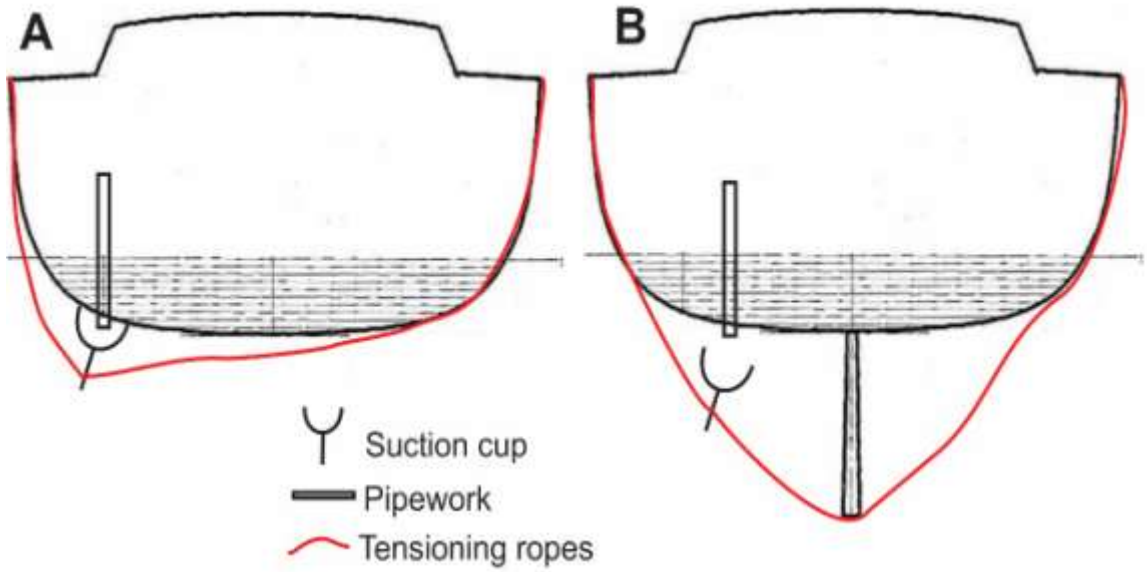
FIELD TESTING – THE CHALLENGES





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OUTCOMES

- Draft treatment protocol completed
- Prototype system is operational **IF** a range of provisos are met
- Incorporated capacity for end-users to refine procedures and apparatus, and validate these changes
- Could be a fully operational system in the future

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