

DEMONSTRATION OF HIGH SHEAR ROTARY MEMBRANE SYSTEM (HSRMS) FOR SHIPBOARD BILGEWATER TREATMENT

WP-201708

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Naval Surface Warfare Center, Carderock Division

Final Debrief
29 September 2022



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| 14. ABSTRACT The technical objective of this project was to demonstrate and validate the full scale performance and integrated operation of an advanced high shear rotary membrane system (HSRMS). | | | | | |
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Technical Objectives

Demonstrate and validate the full scale performance and integrated operation of an advanced high shear rotary membrane system (HSRMS)

- Laboratory Evaluation
 - 1. Demonstrate integrated system operation and performance, reliability, maintainability and availability (RMA) for treatment of multiple simulated bilgewater mixes in a controlled laboratory environment with known feed constituents
 - 2. Determine full scale membrane system fouling rate, failure mode, and regeneration effectiveness in a laboratory environment
 - 3. Assess system operability, required training, and improvements necessary for shipboard installation, operation and evaluation
- Shipboard Demonstration
 - 4. Determine performance for treatment of shipboard produced bilgewater under dynamic operating conditions
 - 5. Calculate system reliability, maintainability and availability shipboard
 - 6. Validate system operability, preliminary operation and maintenance documentation, required training, and production level requirements for approval and use
- Transition
 - 7. Estimate acquisition cost as well as the 30 year operation, maintenance and repair costs
 - 8. Assess risks to ship, shipboard system, personnel and the environment
 - 9. Propose acquisition methodology for system if determined to be ship suitable for Armed Forces vessels

Performance Objectives (I)

- Full Scale Laboratory Demonstration**

| Performance Objective | Data Requirements | Success Criteria |
|--------------------------------------------|-----------------------------------------|--------------------------------------------------------------------------------------------|
| Quantitative Performance Objectives | | |
| System Processing Performance | Oil concentration (ppm) | +95% of effluent samples \leq 15 ppm oil |
| | | +100% of effluent samples \leq 100 ppm oil |
| | | +100% of OWS oil discharge samples $<$ 20% water by volume |
| | Measured alarms, indicators and sensors | +All of system alarms, indicators, and sensors function as designed in all operating modes |
| Fouling Rate | TMP and effluent flow rate | Run time of 300 hrs without reaching 100% resistance |
| Reliability and Maintainability | See RMA Table | |
| Qualitative Performance Objectives | | |
| Regeneration | TMP and effluent flow rate | Regeneration observed |

+OWS Demonstration Protocol Metric ^[1]

Performance Objectives (II)

- Shipboard Validation**

| Performance Objective | Data Requirement | Metric | Success Criteria |
|--------------------------------------|-----------------------|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| System Processing Performance | Logged Operation Data | Oil concentration (ppm) | +95% of OWS \leq 15 ppm Oil in Water Effluent Samples |
| | | | +100% of OWS \leq 100 ppm Oil in Water Effluent Samples |
| | | Measured alarms, indicators and sensors | +All of system alarms, indicators, and sensors function as designed in all operating modes |
| | | Effluent flow rate; Fuel and Water Reports | OWS must be sized to process the daily oily waste generation without accumulation in the OWHT within a 10 hour workday |
| RMA | See RMA Table | | |

*OWS Demonstration Protocol Metric [1]

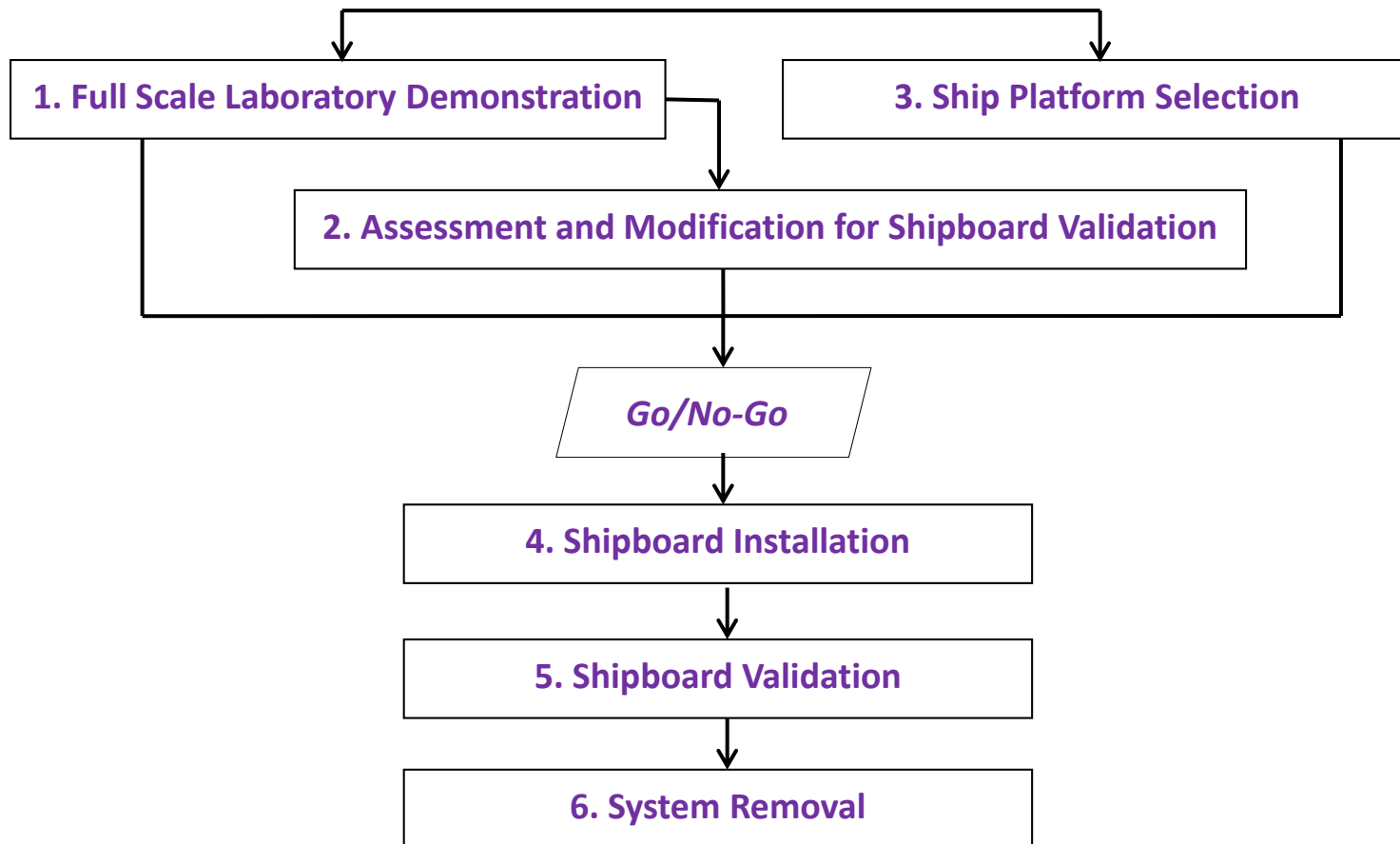
RMA Table (I)

| Performance Objective | Metric Definition | Metric | Success Criteria |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------------------------------------------------------------|
| Reliability | $MTBF = \frac{\text{Total Number of Operating Hours}}{\text{Total Number of Failures}}$ | Logged Operation Data | +MTBF ≥ 922 Hours with No Failures (Relevant Critical or Relevant Major) |
| | $K' = \frac{\text{Total Calendar Time} - \text{Downtime}}{\text{Total Number of Operating Hours}}$ $K'(MTBF) = \frac{\text{Total Calendar Time} - \text{Downtime}}{\text{Total Number of Failures}}$ | | |
| Availability | $A_o = \frac{\text{Uptime}}{\text{Total Time}}$ $= \frac{\text{Uptime}}{(\text{Uptime} + \text{Downtime})}$ $A_o = \frac{(\text{Total Time} - \text{Downtime})}{\text{Total Time}}$ $A_o = \frac{K'(MTBF) - \text{MDT}}{K'(MTBF)}$ $= \frac{1 - [\text{MTTR} + \text{MLDT}]}{K'(MTBF)}$ | Logged Operation Data | +A _o ≥ 95% |

RMA Table (II)

| Performance Objective | Metric Definition | Metric | Success Criteria |
|------------------------|----------------------------------------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintainability | $MLDT = \frac{\text{Total Logistic Time Delay}}{\text{Total Number of Failures}}$ | Logged Operation Data | +MTTR ≤ 3 Hours +Max TTR ≤ 8 Hours +Maintenance Ratio ≤ .03 +Preventative Maintenance ≤ 3.5 Hrs per Week +No Preventative Maintenance Action Shall Take > 16 Man hrs |
| | $MTTR = \frac{\text{Total Corrective Maintenance Time}}{\text{Total Number of Failures}}$ | | |
| | $MDT = \frac{\text{Total Downtime}}{\text{Total Number of Failures}}$ | | |
| | $MDT = (MTTR + MLDT)$ | | |
| | $\text{Maintenance Ratio} = \frac{\text{Total Active Man Hrs}}{\text{Total Operating Time}}$ | | |
| Operability | Training time | Crew/Personnel Interview (see Appendices) | |
| | Operating time | | |
| | Maintenance time (Corrective and Preventative) | | |
| | Operator skill level | Crew/Personnel Interview | Displays skill level required to operate and maintain equipment |

Experimental Design



Demonstration Sites

- **Full Scale Laboratory Demonstration:** NSWCCD Environmental Engineering, Science, and Technology Branch can carry out independent validation and verification testing through use of industrial scale equipment and leading technical expertise in shipboard oil pollution abatement (OPA) research
- **Shipboard Validation:** Military Sealift Command (MSC) USNS MATTHEW PERRY (T-AKE 9)
 - ◆ Prototype oil/water separator previously installed then removed providing ample footprint, existing foundation, and piping connections



NSWCCD Wastewater Lab



USNS Matthew Perry (T-AKE 9)

Laboratory Evaluation

Demonstration site: Naval Surface Warfare Center, Carderock Division

Evaluation Period: March 2018 to September 2018



1) Contaminant mixtures and oil prepared and recirculated in upper level-tanks.



2) Contaminants injected into potable water influent stream using progressive cavity pump or gear pump.

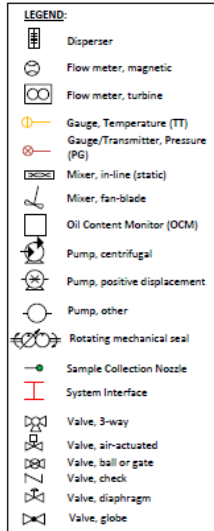


3) Influent processed through system; effluent analyzed by oil content monitors.

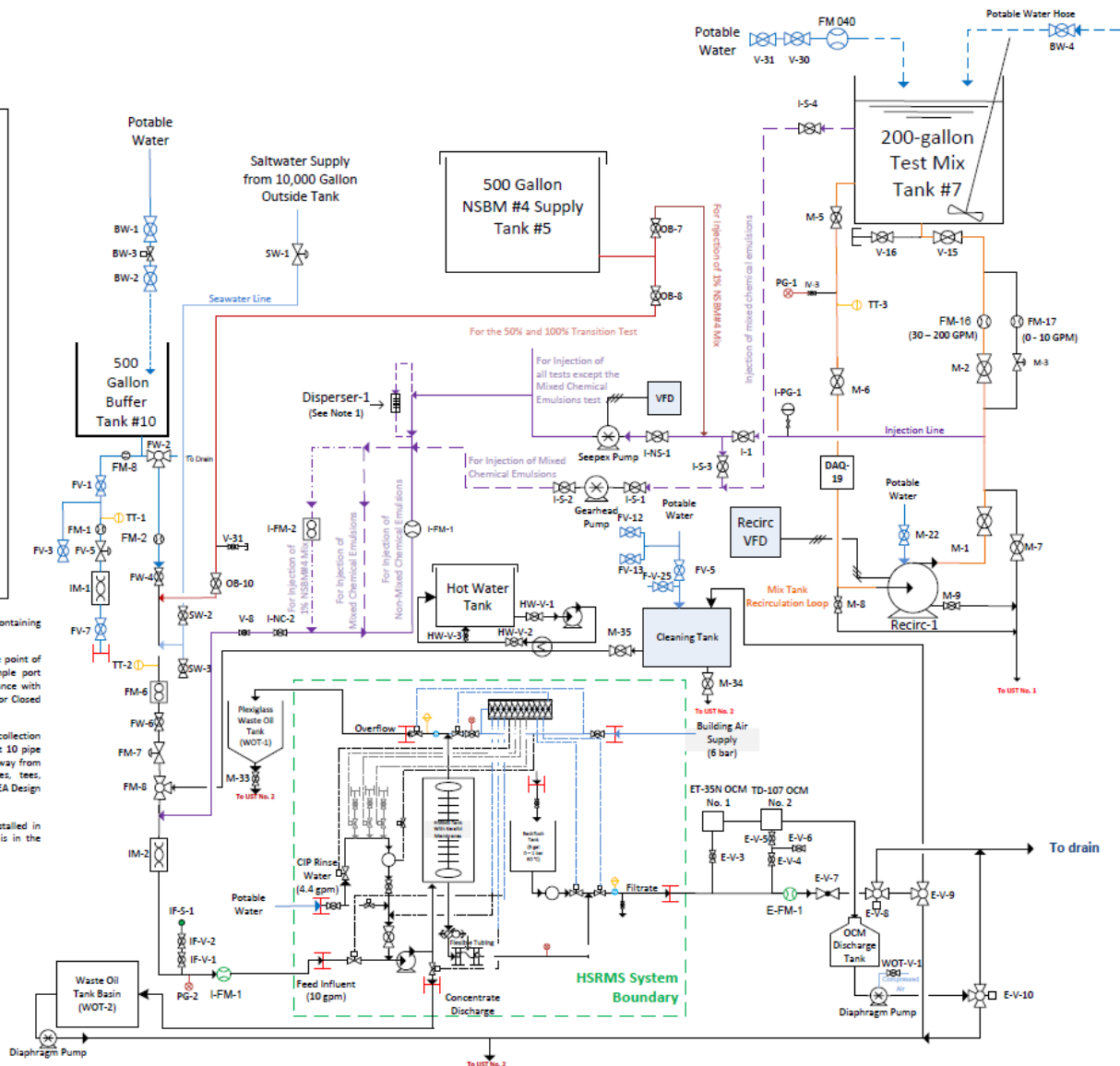


4) Effluent \leq 15 ppm oil sent to drain / wastewater treatment. Effluent $>$ 15 ppm oil sent to underground storage tanks.

Laboratory Evaluation P&ID



- Notes:**
1. Disperser-1 is not used with test mixes containing particles and mixed chemicals.
 2. The minimum pipe length between the point of chemical injection and the influent sample port shall be at least 25 diameters in accordance with "Standard Practices for Sampling Water for Closed Conduits", ASTM D3370, Paragraph 6.1.
 3. Sample collection nozzles and data collection instrumentation shall be installed at least 10 pipe diameters (upstream and downstream) away from the nearest flow disturbers (e.g. valves, tees, pumps, etc.) in accordance with the NAVSEA Design Supplement (NSWCDD-63-TM-2005/35).
 4. Sample collection nozzles shall be installed in vertical piping sections where the flow is in the upward direction.



Performance Test Sequence

| Test # | Test | Influent Mixture | Test Duration | |
|----------|------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|---------|
| 1,11 | Oily Water | 200-ppm NSBM #4 | 10 hours | |
| 2, 12 | Oily Water | 1,000-ppm NSBM #4 | 10 hours | |
| 3, 13 | Oily Water & Mixed Detergent | 1,000-ppm NSBM #4 100-ppm Detergent Mix #4 | 10 hours | |
| 4,14 | Oily Water & Detergent | 1,000-ppm NSBM #4 100-ppm Type 1 Detergent | 10 hours | |
| 5,15 | Oily Water & Mixed Chemicals | 1,000-ppm NSBM #4 0.17% "Clorox" bleach (100 mg/L NaOCl) 0.17% Acetone 0.17% Paint Thinner | 10 hours | |
| 6,16 | Oily Water & AFFF | 1,000-ppm NSBM #4, 100-ppm AFFF | 10 hours | |
| 7,17 | Oily Water, Mixed Detergent, & Particles | 1,000-ppm NSBM #4 100-ppm Detergent Mix #4 100-ppm (m) Arizona Test Dust (coarse) 0.70-ppm (m) Cloth Fibers (lint mostly 25-150 microns in length) | 10 hours | |
| 8,18 | JP-5 Oily Water & Mixed Detergent | 1,000-ppm NSBM #4 JP-5 Variant 100-ppm Detergent Mix #4 | 10 hours | |
| 9,19 | Oily Water & Seawater | 1,000-ppm NSBM #4 35,000-ppm(m) Synthetic Seawater | 10 hours | |
| 10a, 20a | OWHT Transition Test | 1% Oil | 1% NSBM #4 | 6 hours |
| 10b, 20b | | Interface | 50% NSBM #4 and 50% Water | 10 min |
| 10c, 20c | | Bulk Oil | 100% NSBM #4 | 30 min |

Shipboard Evaluation

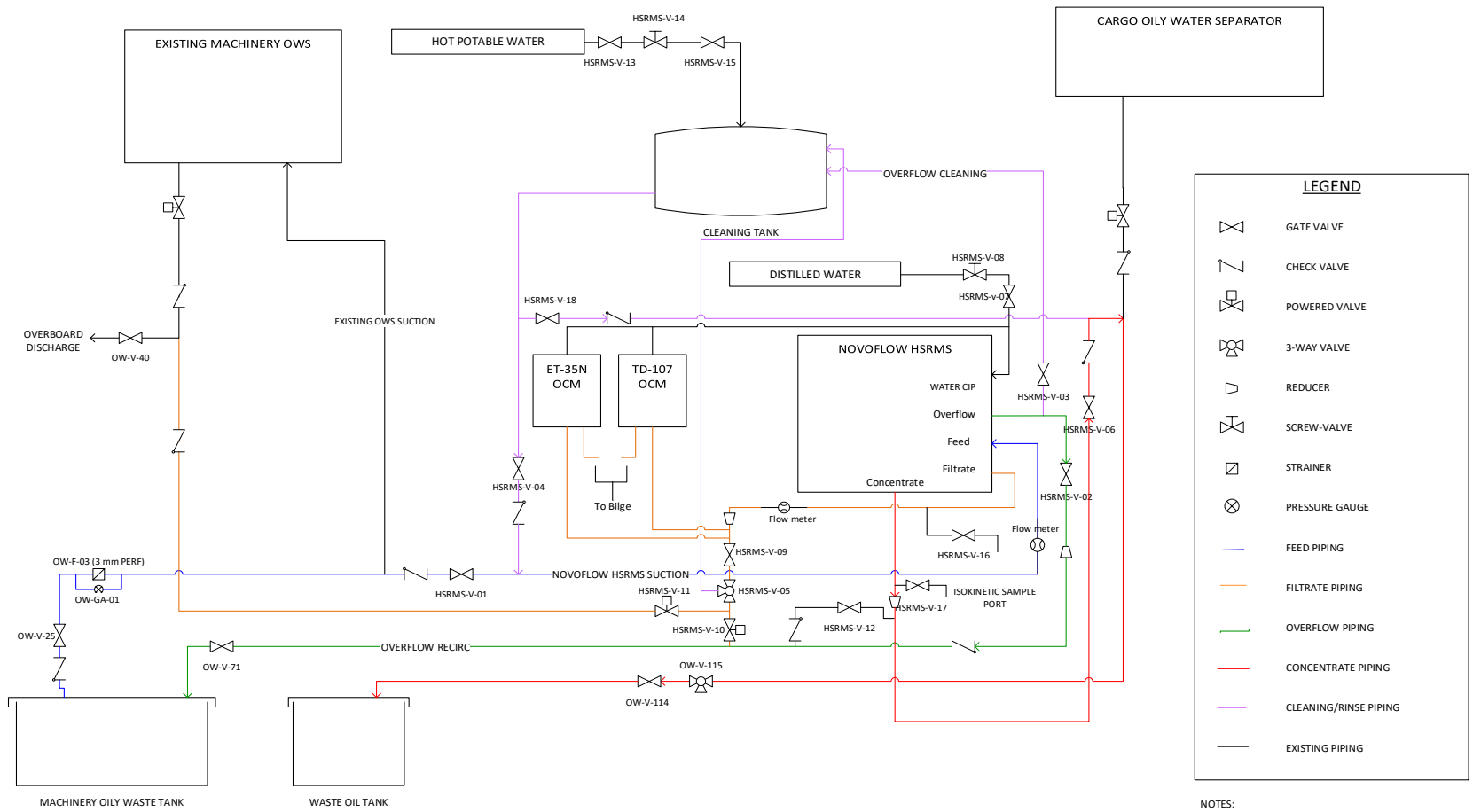
Demonstration site: Military Sealift Command (MSC) USNS Matthew Perry (T-AKE 9)

Installation Period: 26 April to 7 May 2021

Evaluation Period: July 2021 to April 2022



Shipboard P&ID



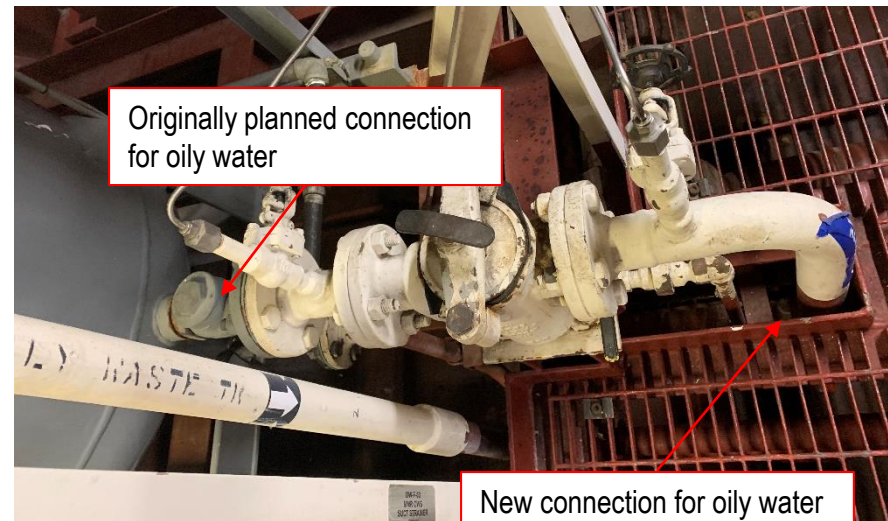
NOTES:
 1) For clarity, not all fitting are shown
 2) Valve labels are subject to change
 3) Novoflow HSRMS does not include piping or valves associated with the system.

Shipboard installation challenges

- **Ship availability (USNS Matthew Perry (T-AKE-9))**
 - Original install date (Nov. 2019) → Contract bid above estimated and available funding
 - Second install date (Jan. 2020) → Ship availability no longer allowed for HSRMS install
 - Third install date (Jan. 2021) → Delayed due to emergent ship schedule changes
 - Fourth install date (May 2021) → HSRMS installed with leveraged NAVSEA 05PF funds

- **Approvals and requirements**
 - U.S. Coast Guard Non- Type Approved OWS Wavier
 - Waiver packages approved (June 2019 and May 2020)
 - ABS Approval
 - Ship installation drawings approved (July 2019 and May 2020)
 - Post installation approval (May 2021)

- **Installation issues**
 - COVID → 2 week ROM before ship access
 - No space for oily waste connection → redesign with new strainer
 - Incorrect installation of 3-way valve
 - OCM discharge to bilge pockets
 - Data logging (failed relay for ET-35N high alarm)



Laboratory Evaluation Results

1. Performance:

- Ability to meet regulatory standards: >95% of effluent samples ≤ 15 ppm
- Alarms, indicators, and sensors work as designed: automatic shutdown at bulk oil processing

2. Membrane Life and Regeneration:

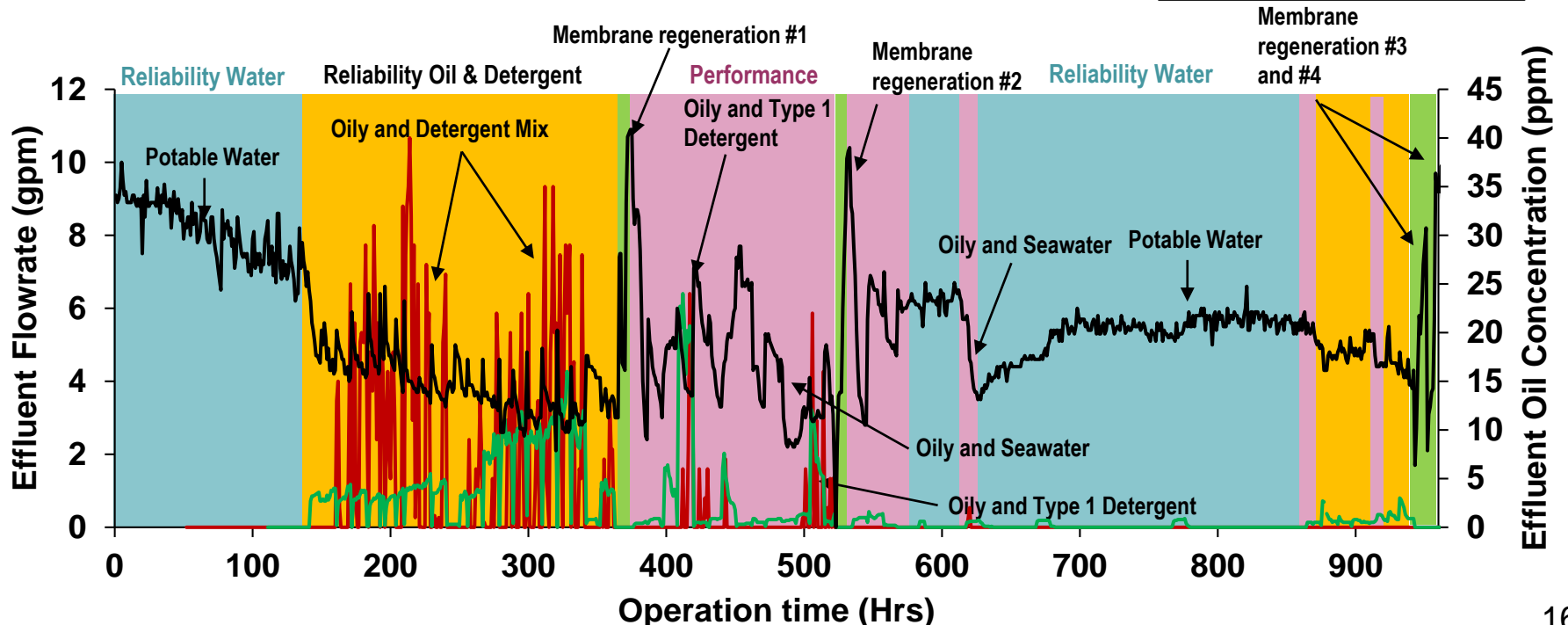
- The membrane was operated for 147-415 hrs before needing chemical cleaning
- Chemical cleaning restored processing capacity up to 67% of initial conditions

3. Reliability, Maintainability, and Availability

- Total system operation of 960 hours
- Silicon carbide seal replaced twice at 50 and 874 hrs of operation



NSWCCD Wastewater Lab

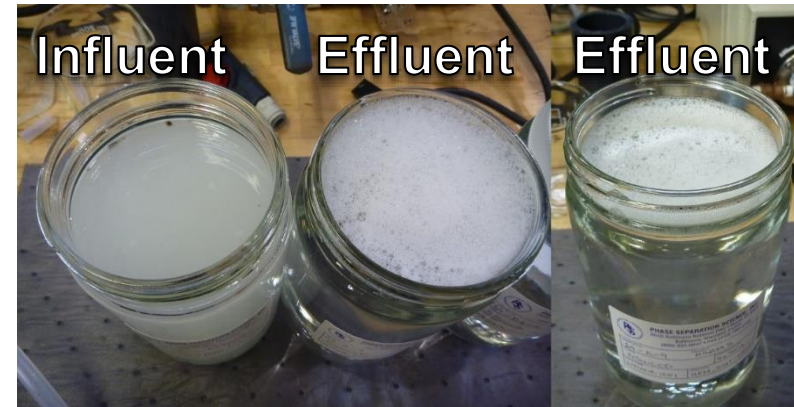


Laboratory Performance Testing Summary

| Performance Objective | Metric Definition | Success Criteria | Laboratory Evaluation | Pass /Fail |
|-------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| System Processing Performance | EPA 1664 Oil concentration | 95% of effluent samples < 15 ppm 100% of effluent samples < 100 ppm | 100% of effluent samples < 15 ppm 100% of effluent samples < 100 ppm | Pass Pass |
| | Measured alarms, indicators and sensors | All alarms, indicators, and sensors function as designed | All alarms, indicators, and sensors functioned as designed | Pass |
| Fouling Rate | Membrane TMP and Effluent Flowrate | Run time of 300 hrs without reaching 100% resistance (or effluent flowrate below 2.2 gpm) | <ul style="list-style-type: none"> • Regen #1 → 352 hrs (140 hr potable water) • Regen #2 → 147 hrs • Regen #3 → 415 hrs (270 hrs potable water) | Fail |

Laboratory Evaluation: Effluent Quality

- The HSRMS produced high quality effluent for all performance tests
- The TD-107 and ET-35N seemed to be sensitive to effluent foam produced during Type 1 Detergent testing (Test 4)



Photos of influent and effluent from oily & Type 1 Detergent Test

| Test Number | Test | EPA 1664 (ppm)* | | TD-107 (ppm)* | | ET-35N (ppm)* | |
|-------------|------------------------------------------|-----------------|-------|---------------|-------|---------------|-------|
| | | Rep 1 | Rep 2 | Rep 1 | Rep 2 | Rep 1 | Rep 2 |
| 1, 11 | 200-ppm Oily Water | ND | ND | 0.6 | 0.4 | 0.0 | 3.0 |
| 2, 12 | 1,000-ppm Oily Water | ND | ND | 0.9 | 0.9 | 0.0 | 2.0 |
| 3, 13 | Oily Water & Mixed Detergent | ND | ND | 3.7 | 1.4 | 4.0 | 4.0 |
| 4, 14 | Oily Water & Type 1 Detergent | 2.5 | ND | 18.2 | 9.8 | 25.0 | 0.0 |
| 5, 15 | Oily Water & Mixed Chemicals | ND | ND | 0.6 | 0.6 | 0.0 | 0.0 |
| 6, 16 | Oily Water & AFFF | ND | ND | 1.0 | 1.0 | 0.0 | 0.0 |
| 7, 17 | Oily Water, Mixed Detergent, & Particles | ND | ND | 2.3 | 1.0 | 1.0 | 4.0 |
| 8, 18 | JP-5 Oily Water & Mixed Detergent | ND | ND | 0.5 | 0.2 | 0.0 | 2.0 |
| 9, 19 | Oily Water & Seawater | ND | ND | 0.8 | 0.7 | 0.0 | 0.0 |
| 10, 20 | OWHT Transition Test | 3.5 | ND | 0.5 | 0.5 | 0.0 | 0.0 |

*Data corresponds to samples taken after 9 hrs for all conditions except for the OHWT Transition Test which was collected at 6 hrs

Laboratory RMA Summary

| Performance Objective | Metric Definition | Success Criteria | Laboratory Evaluation | Pass /Fail |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|-------------------------------------------|------------|
| Reliability | $MTBF = \frac{\text{Total Operating Hours}}{\text{Total Number of Failures}}$ | MTBF \geq 922 Hours with no critical failures | MTBF = 959 Hrs with no critical failures | Pass |
| Maintainability | $MTTR = \frac{\text{Total Corrective Maintenance Time}}{\text{Total Number of Failures}}$ $\text{Maintenance Ratio} = \frac{\text{Total Active Man Hrs}}{\text{Total Operating Time}}$ | MTTR \leq 3 Hours | MTTR = 1 Hr | Pass |
| | | Max TTR \leq 8 Hours | Max TTR = 1.5 Hrs | Pass |
| | | Maintenance Ratio \leq 0.03 | Maintenance Ratio = 0.05 | Fail |
| | | Preventative Maintenance \leq 3.5 Hrs/Wk | Preventative Maintenance = 3.6 Hrs/Wk | Fail |
| | | No Preventative Maintenance Action Shall Take > 16 Man Hrs | Max Preventative Maintenance=11.3 Man Hrs | Pass |
| Availability | $A_o = \frac{\text{Uptime}}{\text{Total Time}}$ | $A_o \geq 95\%$ | $A_o = 97\%$ | Pass |

*Maintenance ratio is high due to membrane cleanings

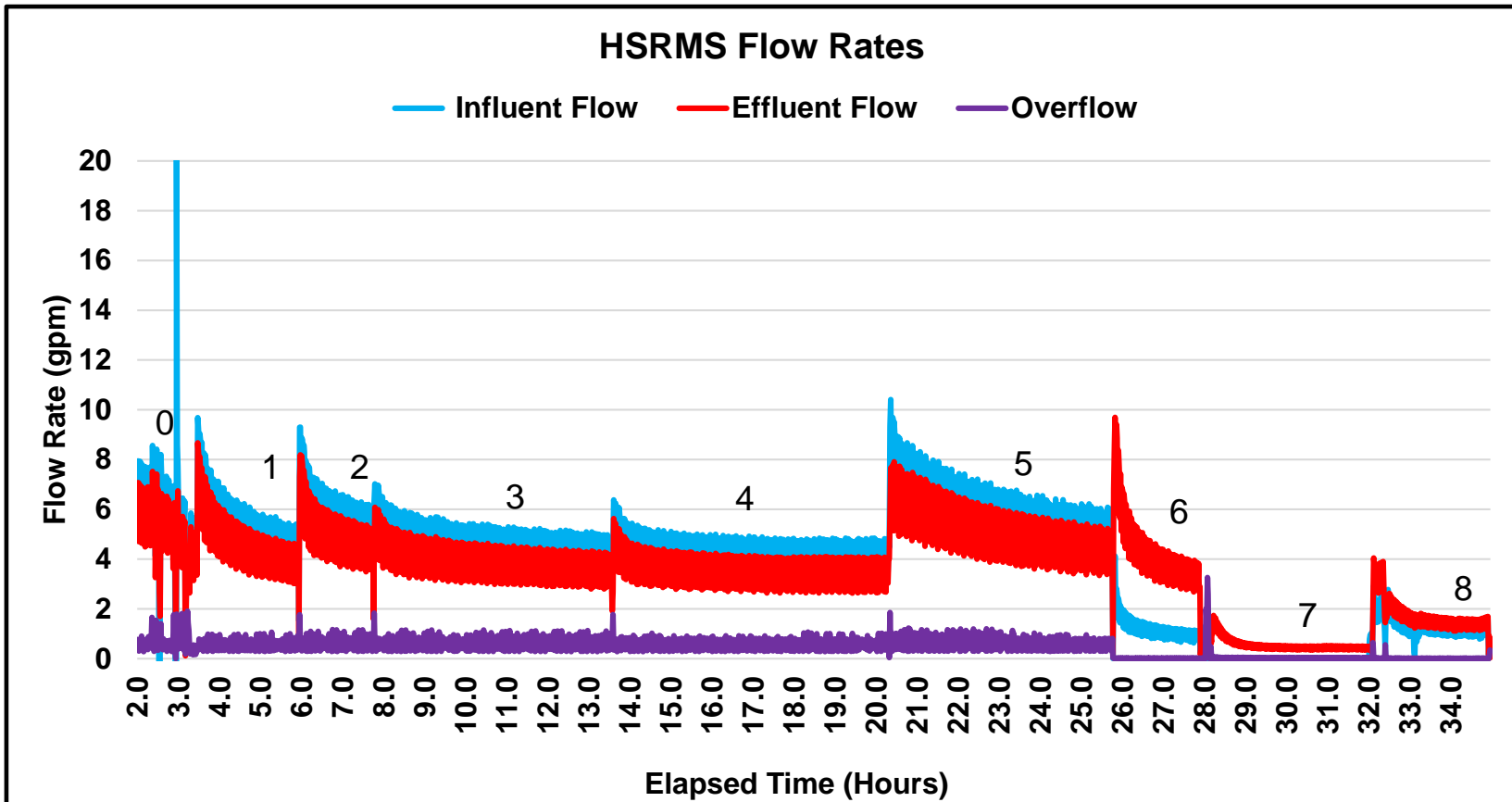
Shipboard Performance Summary

- **Production Hours**
 - 3.4 Install hours
 - 31.5 Underway hours
- **Total volume processed** → 9188 gals
- **Underway volume processed** → 7963 gals

| Performance Objective | Metric Definition | Success Criteria | Shipboard Evaluation | Pass/Fail |
|-------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|---------------------|
| System Processing Performance | Oil Concentration | 95% of effluent samples < 15 ppm | 100% of effluent samples < 15 ppm | Pass |
| | | 100% of effluent samples < 100 ppm | 100% of effluent samples < 100 ppm | Pass |
| | Measured alarms, indicators and sensors | All alarms, indicators, and sensors function as designed | All alarms, indicators, and sensors functioned as designed | Pass |
| Fouling Rate | Membrane TMP and Effluent Flowrate | Run time of 300 hrs without reaching 100% resistance (or effluent flowrate below 2.2 gpm) | 100% resistance after 28 hrs Calculated membrane life= 386 hrs | Inconclusive |

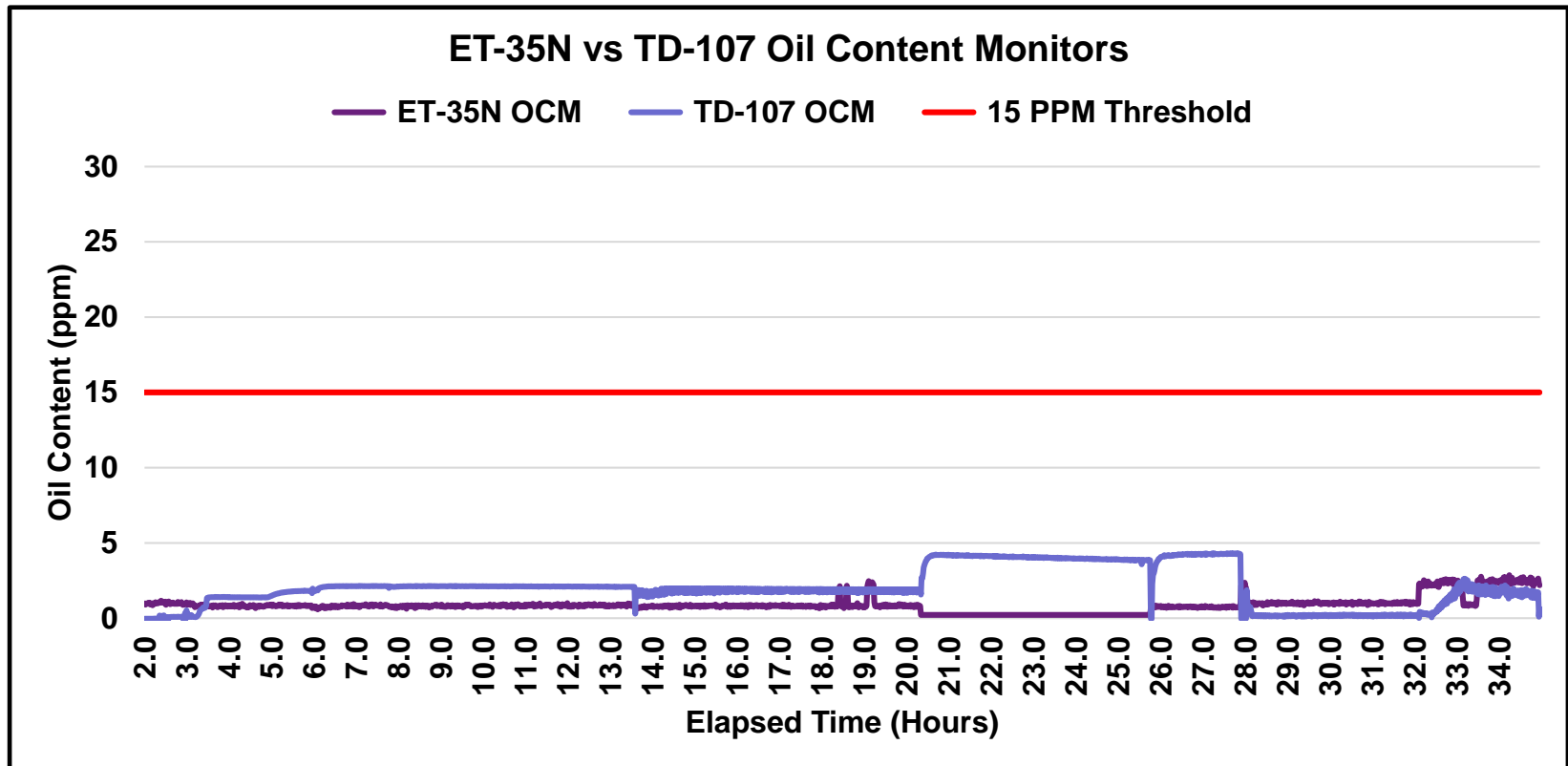
Processing Rate

- 8 production cycles while underway → Average processing rate 4.0 gpm
- No concentrate overflow after 26 hrs → dead end operation, membranes more prone to fouling
- Effluent flowrate greater than influent flow rate → likely due to OCM discharge being redirected or potable water introduced from clean in place system



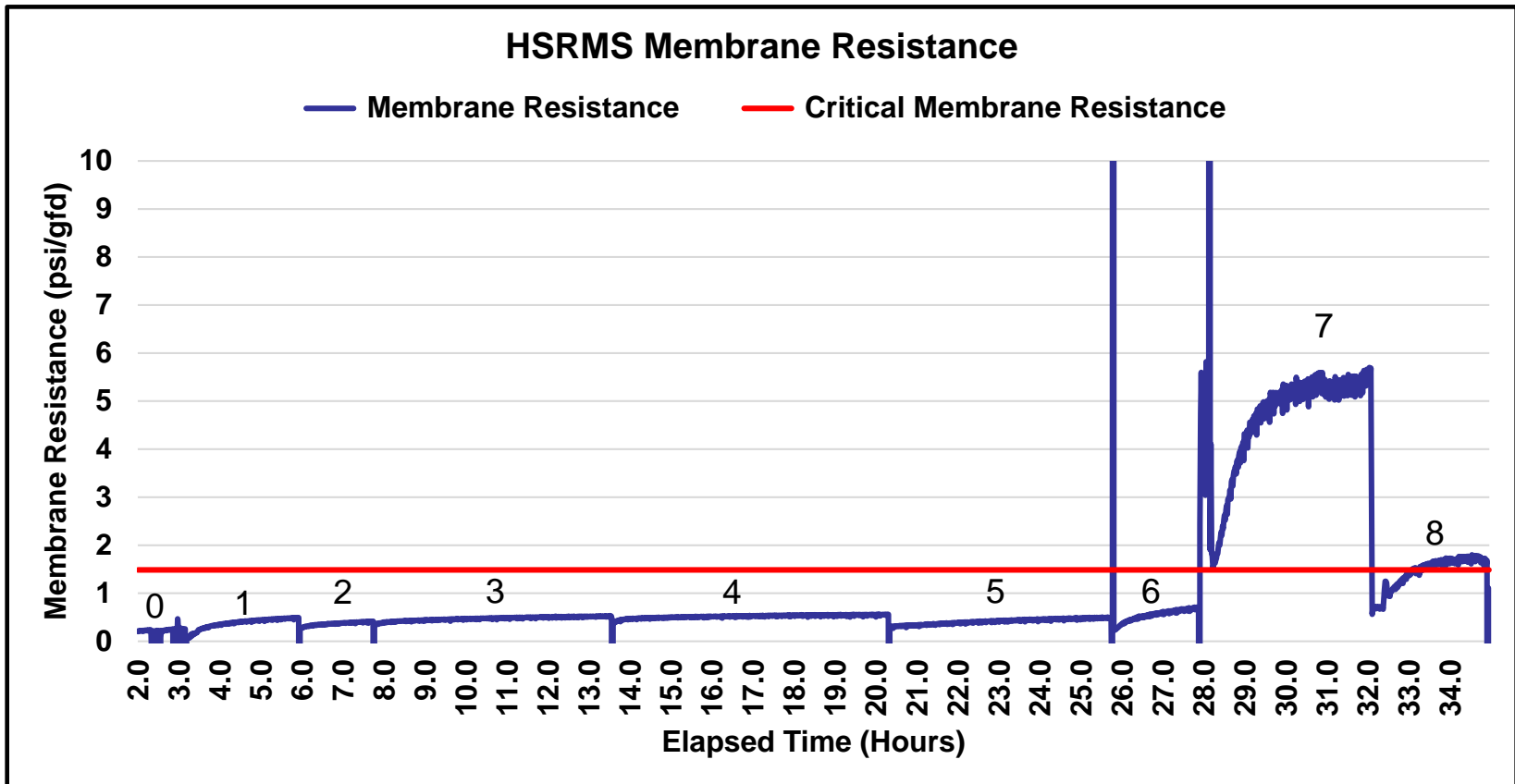
Effluent Quality

- No alarms from TD-107 → made the decision to discharge 100% of the time
- ET-35N oil concentration < 3 ppm for evaluation; alarms were unable to be recorded by data logger
- ET-35N may have been turned off from 20-26 hrs due to discharge filling bilge pockets



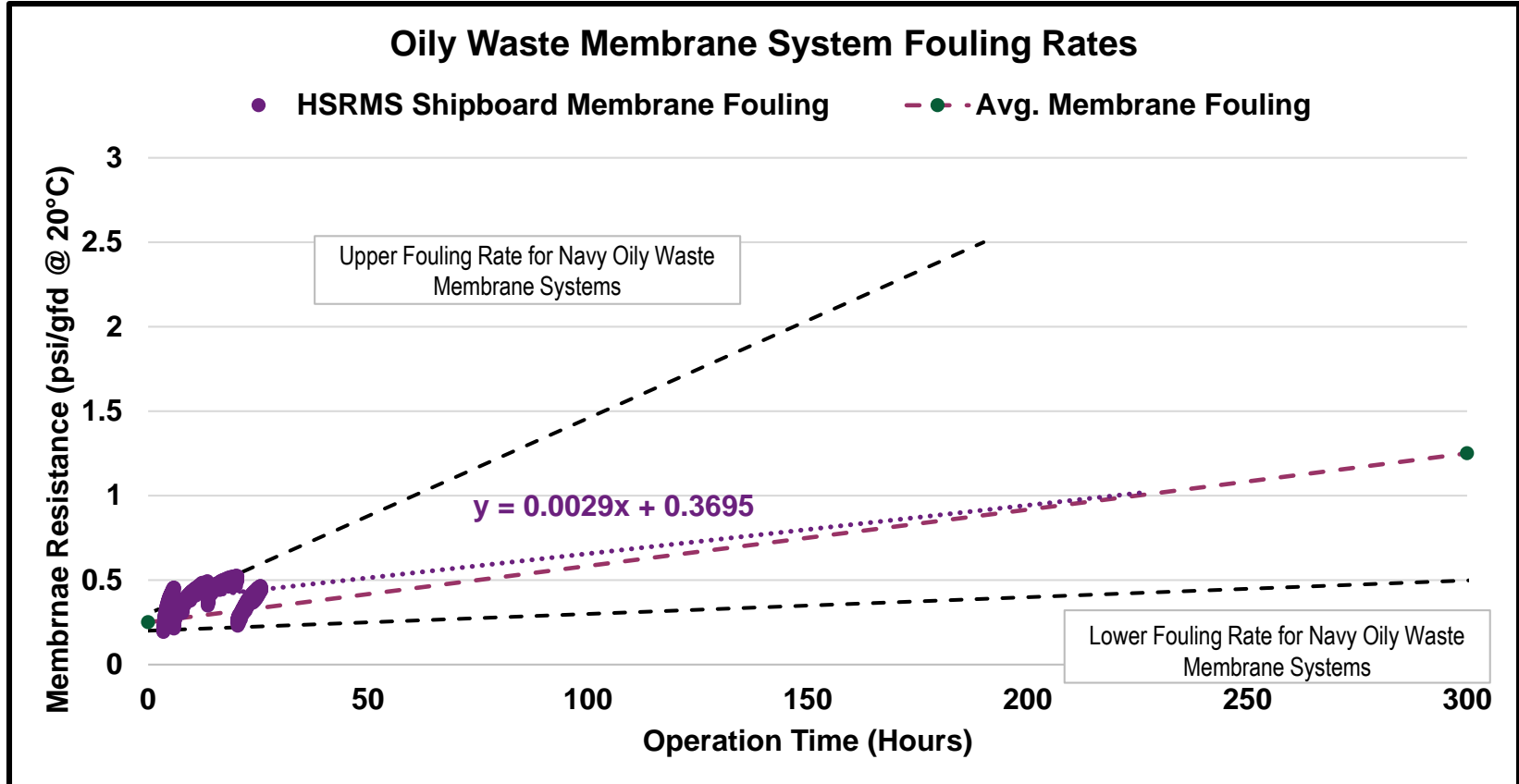
Membrane Life

- Membrane resistance was less than 0.5 psi/gfd for first 28 hrs
- Resistance increased to 5.7 psi/gfd between 28 and 32 hrs
 - No concentrate overflow → dead end operation
 - Strainer cleaned after 32 hrs
- Membrane resistance remained above 1.5 psi/gfd threshold



HSRMS vs Navy OWMS

- Fouling rate is dependent on system design and water quality → highly variable bilgewater water quality leads to highly variable fouling rates (difficult to compare directly)
- Fouling rate of the HSRMS was similar to the avg. fouling rate for current oil water membrane systems → proves technologies potential (smaller foot print, no gravity separator)



Shipboard RMA Summary

| Performance Objective | Metric Definition | Success Criteria | Shipboard Evaluation | Pass/Fail |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------|--------------|
| Reliability | $MTBF = \frac{\text{Total Operating Hours}}{\text{Total Number of Failures}}$ | MTBF \geq 922 Hours with no critical failures | MTBF = 959 Hrs with no critical failures | Pass |
| Maintainability | $MTTR = \frac{\text{Total Corrective Maintenance Time}}{\text{Total Number of Failures}}$ $\text{Maintenance Ratio} = \frac{\text{Total Active Man Hrs}}{\text{Total Operating Time}}$ | MTTR \leq 3 Hours | MTTR = 1.6 Hr | Pass |
| | | Max TTR \leq 8 Hours | Max TTR = 2 Hrs | Pass |
| | | Maintenance Ratio \leq 0.03 | Maintenance Ratio = 0.12 | Fail |
| | | Preventative Maintenance \leq 3.5 Hrs/Wk | Preventative Maintenance = 1 Hrs/Wk | Pass |
| | | No Preventative Maintenance Action Shall Take $>$ 16 Man Hrs | Max Preventative Maintenance=11.3 Man Hrs | Pass |
| Availability | $A_O = \frac{\text{Uptime}}{\text{Total Time}}$ | $A_O \geq 95\%$ | $A_O =$ Inconclusive | Inconclusive |

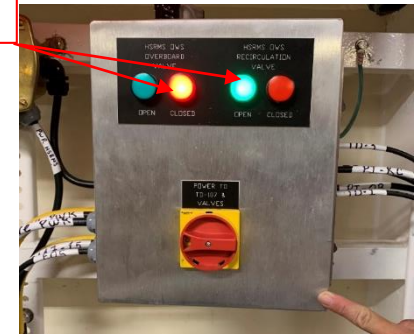
*Maintenance ratio is high due to membrane cleanings

Shipboard HSRMS Reliability

Non-relevant minor failures

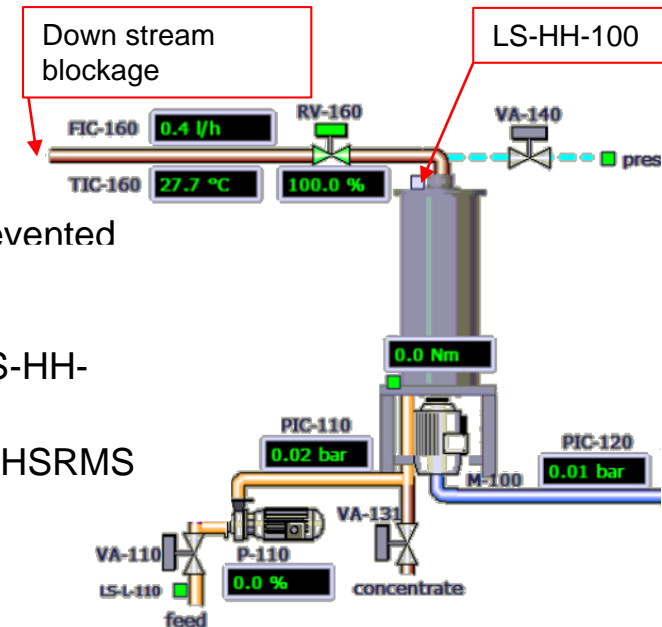
- Overboard indicator light failure (27 July 2021)
 - Indicator light on overboard and recirculation valves failed to illuminate
 - Lights were used as relay for remote alarm in MCCS
 - Indicator lights and remote alarms are not required for operation
- Data logger uninterruptible power supply failure (18 Sept. 2021)
 - Data logger UPS failure
 - No required for data logging or operation

Indicator lights



Non-relevant major failures

- Obstructed Overflow (20 Oct. 2021)
 - Level sensor (LS-HH-100) failed to detect liquid and prevented system start up
 - Sensor cleaned → still issues with start up
 - Overflow was manually opened to allow level sensor (LS-HH-100) to detect fluid to get system to start up
 - Non-relevant failure since blockage was downstream of HSRMS



Relevant minor failure

- VFD failure (13 Aug. 2021)
 - Influent pump VFD was locked due to ship's supply voltage being outside the tolerance range of the VFD
 - NSWCCD provided ships' force instructions on how to redefine tolerances (< 1 hr procedure)

Shipboard HSRMS Maintainability

Preventative Maintenance

- Ships' force was trained on preventative maintenance requirements during system installation
 - Checks for leaks, operation of motors, and mechanical seal leakage indicator
 - Perform 1 minute rinse with potable water during every shut down event
- Ship data and correspondence with ships' forces indicates no potable water rinses were performed
- Strainer was cleaned after 30 hrs per vendor recommendation

Corrective Maintenance

- Adjusted VFD tolerance parameters (est. labor: 1 hr)
 - Checked voltage supply to both VFDs
 - Checked for loose connections
 - Checked parameter 210 on VFDs using vendor instructions
 - Adjusted parameter 210 on VFDs using vendor instructions
- Cleaned level sensor (LS-HH-100) (est. labor: 2.25 hrs)
 - CIP procedure to try to clean sensor in place (unsuccessful)
 - Discharged fluid in membrane housing
 - Removed level sensor (LS-HH-100)
 - Cleaned sensor with rag
 - Replaced level sensor (LS-HH-100)

LS-HH-100



Shipboard HSRMS Operability

Training

- Ship's force was trained by NSWCCD to operate the HSRMS and troubleshoot common issues during system installation.
- CHENG, 1AE, and 3AE were comfortable with system operation.

Ships' force feedback on system operation

“Operating the system is straight forward. The instructions are clear and also we have trained everyone to be able to use it with no problems in lightoff/shut down. Unattended operation - there is no issue here. If anything.. the only monitoring we have to do is with the amount it [OCM discharge] fills up the bilges but that has already been addressed.”-
1AE Figueroa (10 Aug. 2021)

“Basically they were not happy with the operation of the HSRMS. It had a very low capacity of production and used a lot of water doing flushes. We have not operated it since I arrived on the ship in November.”-
CHENG Corey (3 Mar. 2022)

Cost Assessment

- Cost benefit showed a positive 30 year cost savings of \$1,066K
- Largest cost savings were attributed to start-up and maintenance costs
- Cost of ruggedization and ILS will have a large impact on cost benefit

| | Baseline Technology | Alternative Technology | Cost Benefit |
|----------------------|---------------------|------------------------|------------------|
| Direct Costs | | | |
| Start-up Cost | \$ 399K | \$ 233K | \$166K |
| Operation Cost | \$ 68K | \$ 68K | \$0K |
| Maintenance Cost | \$ 1,724K | \$ 818K | \$906K |
| Indirect Cost | | | |
| Wastewater Disposal | \$ 130K | \$ 155K | (-\$25K) |
| 30 year ROI | | | \$ 1,066K |

Scale-up

- Position level sensors to avoid fouling from oil
- Implement automatic clean water flush protocol during system shutdown
- Redesign to avoid the use of variable frequency drives (VFDs)
- Improve integration with OCMs (e.g. backflush frequency, required backpressures, etc.)
- Militarized HSRMS design for shock, vibration, EMI and other requirements (e.g. cyber security, etc.)
- Additional performance and reliability testing as needed

Next Steps

- Redesign HSRMS technology for shipboard applications
 - ◆ Position level sensors to avoid fouling from oil
 - ◆ Implement automatic clean water flush protocol during system shutdown
 - ◆ Redesign to avoid the use of variable frequency drives (VFDs)
 - ◆ Improve integration with OCMs (e.g. backflush frequency, required backpressures, etc.)
 - ◆ Militarized HSRMS design for shock, vibration, EMI and other requirements (e.g. cyber security, etc.)
 - ◆ Additional performance and reliability testing as needed

- Develop methods to extend membrane life
 - ◆ Backflushing
 - ◆ Clean in place
 - ◆ Membrane regeneration
 - ◆ Coatings

- Evaluate future ship needs
 - ◆ Footprint of future ship classes
 - ◆ Future discharge regulations

Technology Transfer

- Regular briefs with NAVSEA 05P5 to transfer knowledge to stakeholders.
- Transition of knowledge to the general research community
 - 2020 AWWA Membrane Technology Conference
- Transition of knowledge to federal research community
 - 2022 Water Treatment Interagency Working Group Meeting

Key Points

- The HSRMS was able to treat bilgewater in a shipboard environment to below regulated concentrations
 - ◆ All OCM readings were below 15 ppm
 - ◆ No recorded TD-107 OCM alarms
- Shipboard processing rate of the HSRMS averaged 4.0 gpm, similar to laboratory evaluation and would need to be resized for future Navy applications
- Observed membrane fouling was similar to current Navy crossflow ultrafiltration systems but with lower pressures and the potential smaller footprint
- The Novoflow HSRMS was not designed for shipboard applications
 - ◆ No automatic rinse function during shut down
 - ◆ VFD sensitive to ship's voltage supply
 - ◆ Location of level sensors are subject to oil fouling
 - ◆ Overflow recirculates back to MOWT (bilge tank)
- Shipboard results indicate HSRMS as a promising technology for bilgewater treatment if packaged for DoD shipboard application

BACKUP SLIDES

WP-201708: Demonstration of Stacked HSRMS for Shipboard Bilgewater Treatment

Performers

- Ms. Danielle Paynter, Principal Investigator, NSWCCD Code 633
- Dr. Jared Church, Co-Principal Investigator, NSWCCD Code 633

Technology Focus

- HSRMS is a potential solution for removal treating bilgewater including emulsions; the system has added benefits including decreased footprint, more efficient design and lower membrane cost as compared to conventional bilgewater treatment technologies

Demonstration Objectives

- Execute a full scale laboratory evaluation and if suitable, conduct shipboard validation to determine system performance in treating shipboard produced bilgewater, maintenance and operability requirements.

Project Progress and Results

- All laboratory evaluation objectives have been completed; actions related to the shipboard installation are in progress with a planned installation between March – May 2021 and validation between May – November 2021.

Implementation Outlook

- NSWCCD is on target for system installation and validation objectives
- Concerns surround HSRMS's ability to pass military qualifications (Shock, Vibration, and Electromagnetic Interference (EMI))

