VESSEL-GENERATED UNDERWATER RADIATED NOISE COMPARISON STUDY (TUGS): *EWOLF, TIOGA, AND LEADER*

MARITIME ADMINISTRATION
META PROGRAM

SUMMARY BRIEFING

PROJECT GOALS

- **Compare underwater noise generated by battery-electric and conventional diesel propulsion vessels**
- **Identify potential underwater noise reductions that can be linked to vessel designs with reduced greenhouse gas emissions**

Measured Vessels

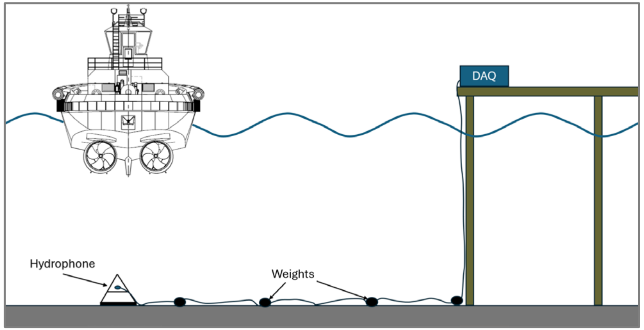
eWOLF
Z-Drives, Battery-Electric

Tioga
Z-Drives, Hard Mounted Diesel Engines

Leader
Voith, Hard Mounted Diesel Engines

MEASUREMENT CONDITIONS

- **Transit Conditions**
  - 10, 8, 6, 4, and 2 knots
  - Four vessel transits per condition
- **Simulated Tug Assist (STA) Conditions**
  - Power:100%, 80%, 60%, 40%, and 20%,
    - Based on RPM/Pitch
  - Each condition measured 3 times
- **Background Noise**



Deployment Arrangement Schematic

STA Test, *Leader*

PROCESSING OVERVIEW

- **For Each Measurement:**
  - Background noise spectrum determined
  - Received level at hydrophone measured
    - **Transit:** Time of maximum level verified as the Closest Point of Approach (CPA)
    - **STA:** minimum 30 seconds of data used (vessel stationary over hydrophone)
    - Process noise spectrum at hydrophone
      - If transit, data at CPA +/- 30 degrees (per ANSI S12.64)
      - If STA, all data used
    - Data inspected for clear signs of interference; reject as necessary
    - Noise spectrum background corrected as necessary (per ANSI S12.64)
  - Distance corrected 1-meter source level calculated using spherical spreading
    - $20*\log_{10}(d)$, where d is the distance between the hydrophone and the vessel at CPA
- **Data averaged over multiple runs for each measured vessel/condition**

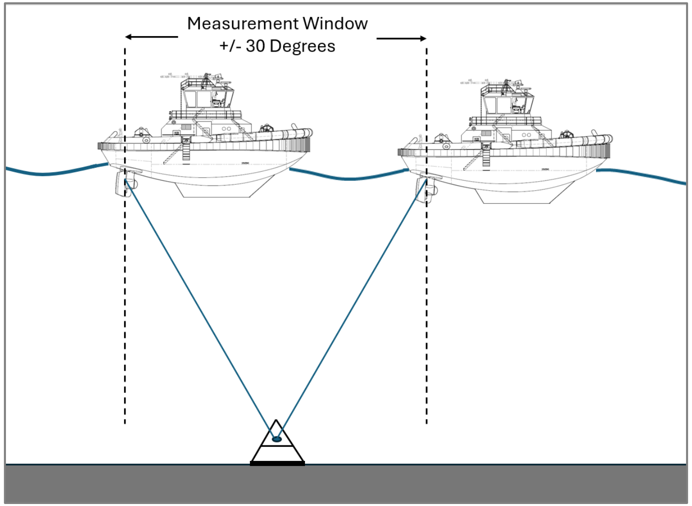
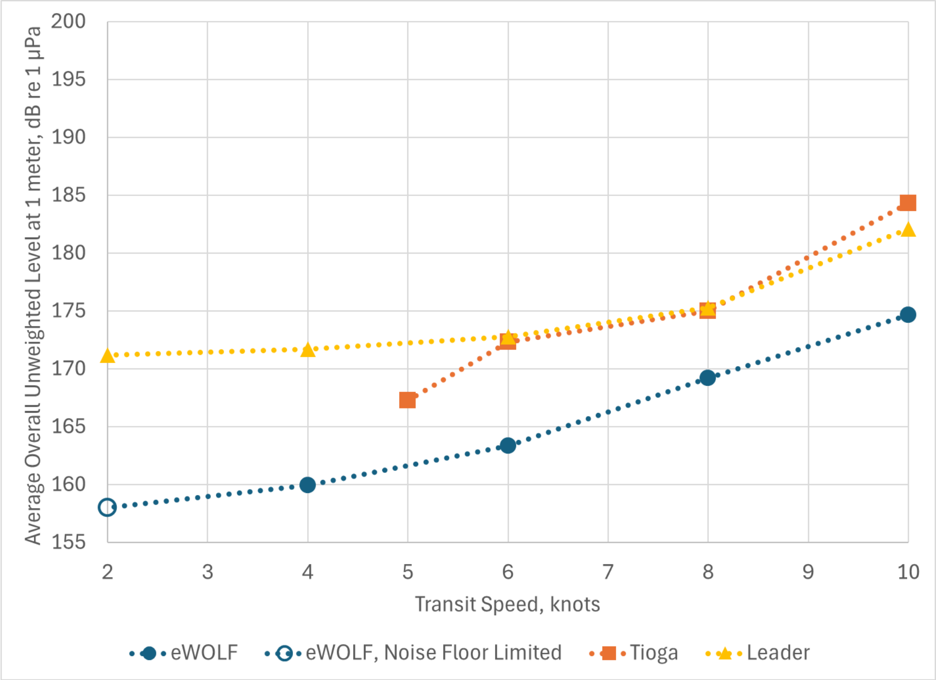


Diagram of Measurement Window

OVERALL LEVELS: TRANSIT CONDITIONS

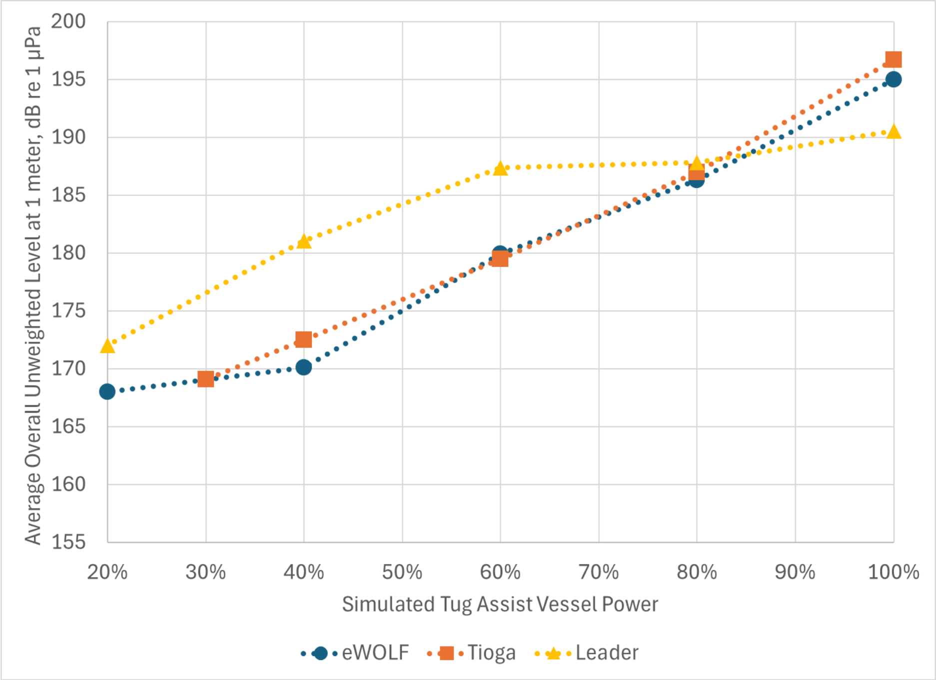
- **At all transit speeds, the *eWOLF* overall level is at least 6 dB lower than those of the *Tioga* and *Leader* at comparable speeds**
- **"Hard mounted" diesel engines of *Tioga* and *Leader* main cause of higher levels**
  - Difference could potentially be reduced with noise control treatments for propulsion engines



Transit Condition, Average Overall Levels at 1-meter

OVERALL LEVELS: STA VS. POWER

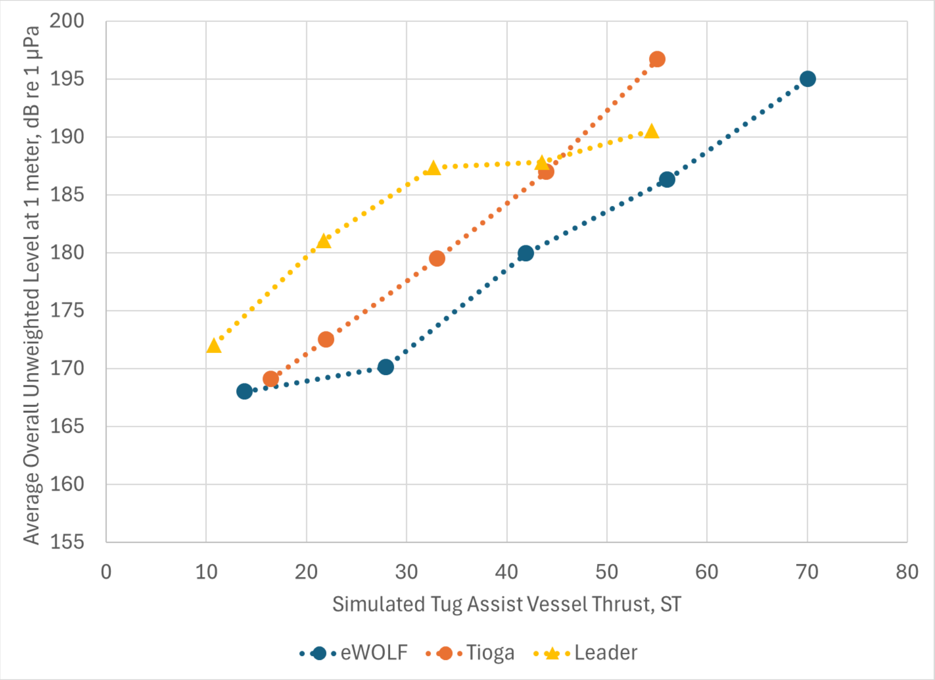
- **At all STA Conditions, *eWOLF* noise is similar to or louder than the other vessels**
  - Comparison uses percent of installed power
- ***eWOLF* propellers produce significant noise once cavitation is present, similar to *Tioga***
  - Propeller noise from the *Leader* is generally lower than other vessels because the Voith Schneider propulsion system cavitation is minimal
  - Engine noise controls *Leader* levels



STA Condition, Average Overall Levels at 1-meter vs. Percent Power

ALTERNATE ASSESSMENT: STA NOISE VS. THRUST

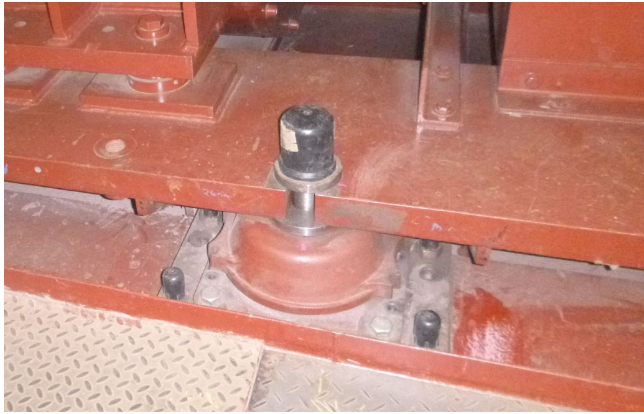
- **Estimates of thrust during STA conditions were provided after finalization of the report**
  - Thrust estimation based on Crowley-measured thrust at 100% bollard pull with scaling for engine power
- ***eWOLF* noise is at least 5 dB lower than *Tioga* and *Leader* at thrusts over 25 short tons**
  - Thrust comparison has greater relevance to tug assist operations.
    - *eWOLF* quieter when performing the same work as other vessels
  - *eWOLF* uses a larger and slower turning propeller than *Tioga*
    - Tends to reduce cavitation



STA Condition, Average Overall Levels at 1-meter vs. Estimated Thrust

CONCLUSIONS

- **Underwater noise reductions for tugs are possible by implementing battery-electric propulsion systems**
  - Limited to slower speed transit and low power tug assist operating conditions when propeller cavitation is not present or is minimal
  - Impact on noise reduction will be further diminished when compared to tugs that have applied noise controls to their diesel engines
- **Noise reduction at higher speeds and STA conditions requires design stage efforts to reduce cavitation**
  - Conventional propeller designs with reduced cavitation may be possible if implemented as goal at the design stage
  - Alternative propulsion systems present opportunities to reduce cavitation (e.g. cycloidal systems)



Resilient Mount

Voith Schneider Propellers on Drydocked Vessel