GREEN BOATS AND PORTS FOR BLUE WATERS
UNIVERSITY OF RHODE ISLAND
GRADUATE SCHOOL OF OCEANOGRAPHY

Certified Energy Manager and Auditor
Certified Power Quality Professional
USCG Licensed Chief Engineer
Senior Engineer, Navis Energy Solutions
Norfolk, VA

April 5, 2016
PRESENTATION TOPICS

- Energy Efficiency (Cultural and Technical)
- Fishing Vessel Energy Efficiency Project
  - Alaska Fisheries Development Foundation (AFDF)
  - Alaska Longline Fishermen’s Association (ALFA)
  - Energy Analysis Tool (EAT): Baseline Energy Consumption and Cost
- ECMs
  - Refrigeration and HVAC
  - Hydraulics
ENERGY EFFICIENCY: CULTURAL

Cultural ECMs Typically have the greatest return on investment but most difficult to implement

- Training
- Energy Management Program
- Energy Surveys/Retro-commissioning

Same Space:
A/C set to 40°F
Electric Heater On
Reduction in Energy from:

- Turning off equipment that is not required
- Operating running equipment more efficiently
- Modifying operating procedures
ENERGY EFFICIENCY: TECHNICAL

Minimize losses in conversion of chemical fuel energy to rotational torque energy from engine

- Improve engine efficiency
- Utilize waste energy from conversion process
Improve Electrical Conversion Process:

- Use high efficiency equipment: Motors, Transformers, Lights, Inverters
- Do NOT oversize equipment
Fishing Vessel Energy Efficiency Project

Phase 1 complete, Phase 2 ongoing

Collaboration

Performed Energy Audits on 12 Fishing Vessels Phase 1 and 6 vessels so far in Phase 2
Fishing Vessel Energy Audit Project

4 Step Approach

1) Develop an operational profile for the vessel
2) Establish baseline energy loads for each profile
3) Identify high energy consumers
4) Research ECM appropriate for the vessel
   - Implement during upgrades

“Follow the money. That’s energy management.”
Mike Gaffney
Fishermen enter vessel and equipment particulars as well as operational profile into tool. The tool uses this data to create a baseline of energy cost and consumption.
Operate at most fuel efficient speed when possible
Properly sized engines increase fuel efficiency
Fishing Vessel Energy Efficiency Project
Energy Analysis Tool
Beta Version – Microsoft Excel Spreadsheet

Vessel Summary: This tab displays the overall fuel consumption of your vessel. The table shows the gallons of fuel consumed by each load type in each operating mode.

<table>
<thead>
<tr>
<th></th>
<th>Longline</th>
<th>Trolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Propulsion</td>
<td>500</td>
<td>199</td>
</tr>
<tr>
<td>Fishing propulsion</td>
<td>266</td>
<td>202</td>
</tr>
<tr>
<td>DC Load</td>
<td>91</td>
<td>53</td>
</tr>
<tr>
<td>AC Load</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hydraulic Load</td>
<td>265</td>
<td>68</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>0</td>
<td>1,661</td>
</tr>
<tr>
<td>Total</td>
<td>1,123</td>
<td>2,183</td>
</tr>
</tbody>
</table>

Total Fuel Consumption: 3,307 gallons

Baseline Enables ECM Analysis
FISHING VESSEL ENERGY EFFICIENCY PROJECT
ECM: HVAC/ REFRIGERATION EFFICIENCY

*Coefficient of Performance* (C.O.P.)

= \( Q \) (heat moved) \( ÷ \) \( W \) (electrical energy used)

- C.O.P. = \( 3 \) kW \( ÷ \) \( 1 \) kW
- C.O.P. = 3
  - (Higher is more efficient)
FISHING VESSEL ENERGY EFFICIENCY PROJECT
REFRIGERATION COMPRESSOR EFFICIENCY

Discharge Pressure (Pd)
Condensing Water Temp

Total Lift (Pd - Ps)

Efficiency increases as total lift decreases

Suction Pressure (Ps)
Chill Water Temp
Compressor efficiency increases as lift decreases.
Refrigeration capacity increases as lift decreases.
Refrigeration Compressor Efficiency

Refrigerated Sea Water Compressor: Power VS. Compressor Discharge Pressure

- **180 PSI**: $18,000 Fuel / 2,000 hrs of operation
- **160 PSI**
- **140 PSI**: $13,800 Fuel / 2,000 hrs of operation

**Profits increase as lift decreases**
Refrigeration Efficiency (Ship System)
Increase Suction Pressure to Reduce Lift

33% Power reduction with decrease in lift
(14°F to 50°F)
# Shipboard HVAC Cost

## Maximize Compressor Efficiency

<table>
<thead>
<tr>
<th>AC Motor COP</th>
<th>Ship's power Inport ($/yr)</th>
<th>Shore Power Inport ($/yr)</th>
<th>Total Inport Cost ($/yr)</th>
<th>At Sea Cost ($/yr)</th>
<th>Total Annual Energy cost ($/yr)</th>
<th>Total Fuel (gal/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>$228,774</td>
<td>$89,205</td>
<td>$317,979</td>
<td>$343,111</td>
<td>$661,090</td>
<td>142,971</td>
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<tr>
<td>4.5</td>
<td>$279,612</td>
<td>$109,029</td>
<td>$388,641</td>
<td>$419,358</td>
<td>$807,999</td>
<td>174,742</td>
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<tr>
<td>3.5</td>
<td>$359,501</td>
<td>$140,180</td>
<td>$499,681</td>
<td>$539,174</td>
<td>$1,038,856</td>
<td>224,669</td>
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<tr>
<td>2.5</td>
<td>$503,302</td>
<td>$196,252</td>
<td>$699,554</td>
<td>$754,844</td>
<td>$1,454,398</td>
<td>314,536</td>
</tr>
</tbody>
</table>
FISHING VESSEL ENERGY EFFICIENCY PROJECT
REFRIGERATION VFD APPLICATION

VFD: Most efficient way to control compressor capacity

ALFA trials underway this fishing season with energy meters to document energy savings
FISHING VESSEL ENERGY EFFICIENCY PROJECT
REFRIGERATION VFD APPLICATION

VFD: Introduce harmonics into the motor

Ensure grounding and generator sizing is as per MFG guidelines

Voltage and Current waveform without VFD

Voltage and Current waveform with VFD
ALFA trials to measure actual hydraulic loads over the next few months

Data collected will provide more accurate energy baseline
## Hydraulic Systems: F/V Myriad

<table>
<thead>
<tr>
<th>Activity</th>
<th>Measured Fuel (GPH)</th>
<th>Change (GPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trolling with hydraulics OFF</td>
<td>1.47</td>
<td></td>
</tr>
<tr>
<td>Trolling with hydraulics ON</td>
<td>1.68</td>
<td>-0.22</td>
</tr>
<tr>
<td>Trolling while Running Gear w Hydraulics</td>
<td>1.74</td>
<td>-0.27</td>
</tr>
</tbody>
</table>

### Energy Analysis Tool: Vessel Profile Page

- **Ave Hourly Hydraulic Loss Cost**: $1/hr
- **No Load Hydraulic Fuel Cost on All the Time (1,205 hrs)**: = $1,205

**Only Engage Hydraulics When Needed for Useful Work**

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Name (ie. Ice troll, gillnet, family outing)</th>
<th>Propulsion Engine #1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hrs Transit</td>
</tr>
<tr>
<td>1</td>
<td>Longline</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>Ice troll</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>Freeze troll</td>
<td>160</td>
</tr>
<tr>
<td>4</td>
<td>family</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>395</strong></td>
</tr>
</tbody>
</table>
Losses in converting shaft power to hydraulic power to electrical power.
Fishing Vessel Energy Efficiency Project

All About the Boats: Vessel Energy and Fuel consumption
THANK YOU!