# Fishing Vessel Energy Audit Project

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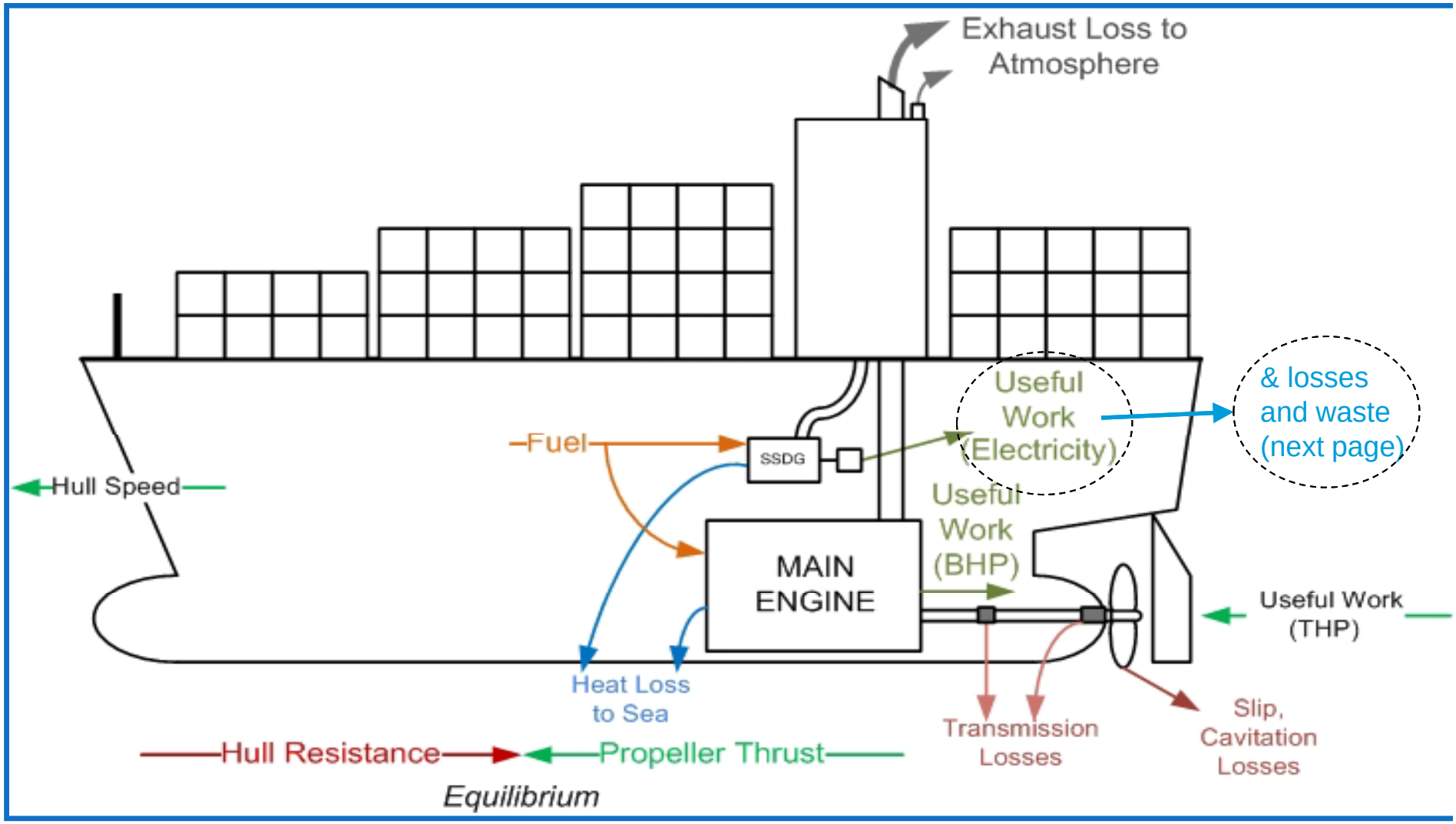
Seattle, WA

# Outline

- Energy Efficiency: The Big Picture
- Baseline: Why Do We Need One?
- Hull Power and Engine Efficiency
- A/C Power
- D/C Power
- Refrigeration System
- Hydraulic System

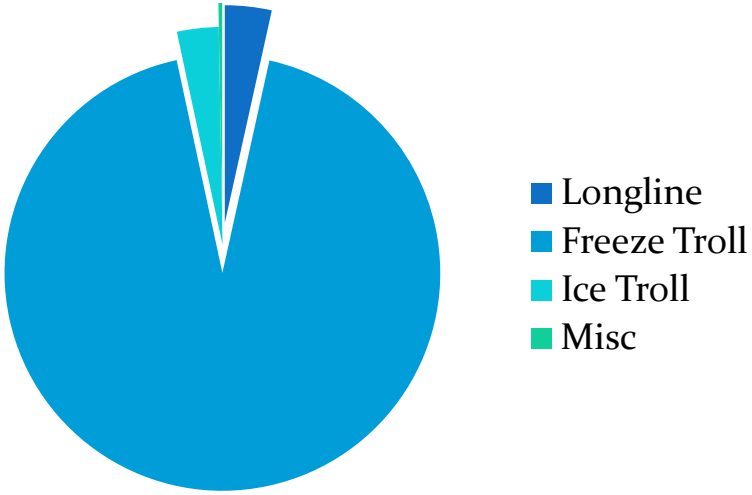
**Goal: Reduce Cost**

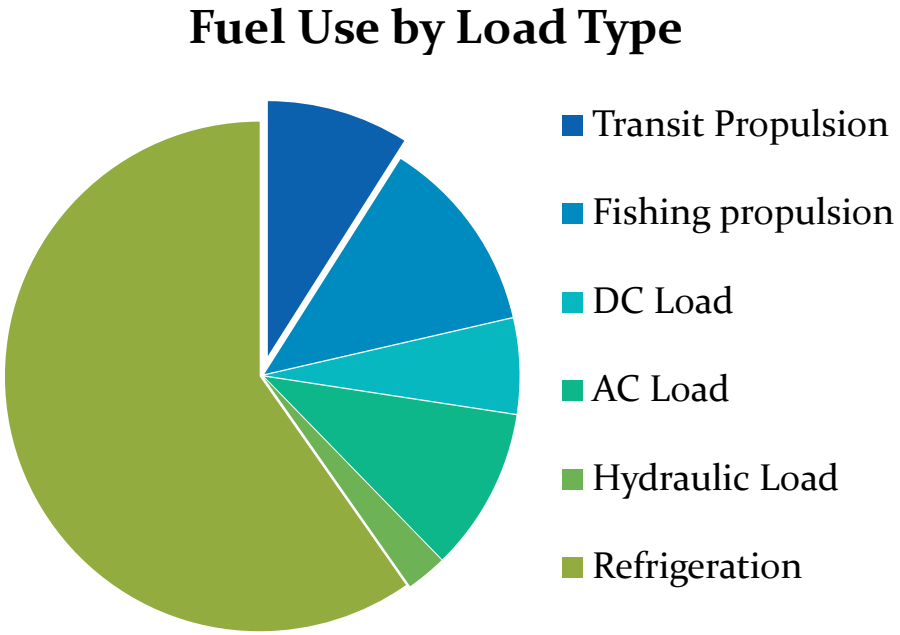
# Ship Energy Efficiency: The Big Picture



# Baseline

- Reference point in which analysis is done
- Better baselines provide better information for informed decisions
- Purpose of doing energy survey
- Energy Analysis Tool (E.A.T.): Helps fisherman develop their baseline of energy cost




F/V Example, E.A.T. Summary

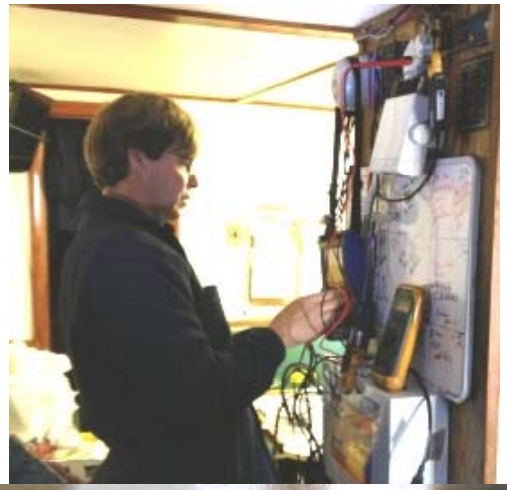
# Baseline: Energy Audit Measurements

Energy Audit Measurement Accuracy

- Relative Accuracy
- Absolute Accuracy

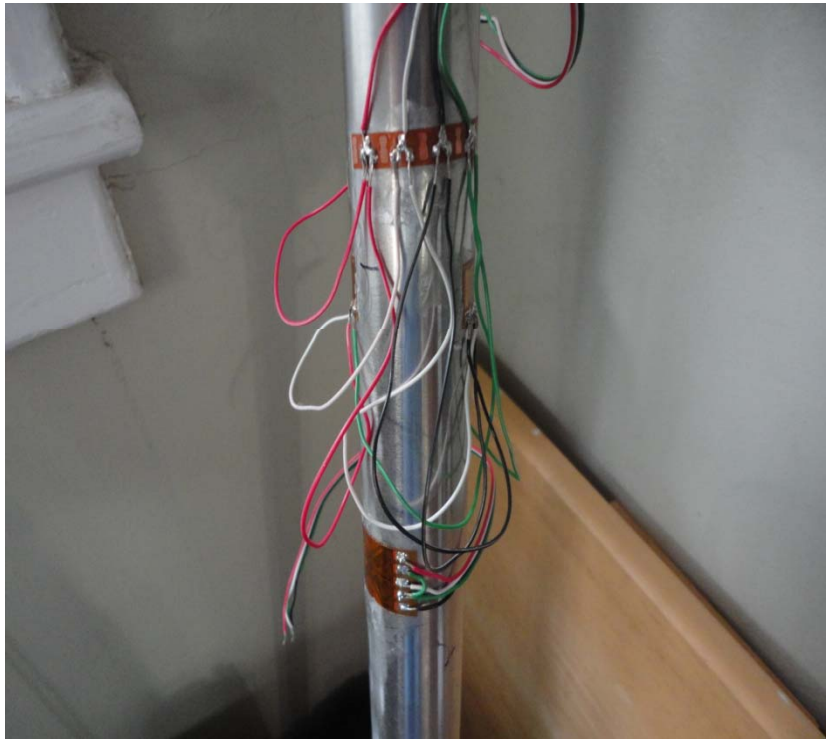
Measurement instruments

- Torque Meter
- Power Quality Meters
- Amp Meter
- Voltage Meters
- Infrared Camera

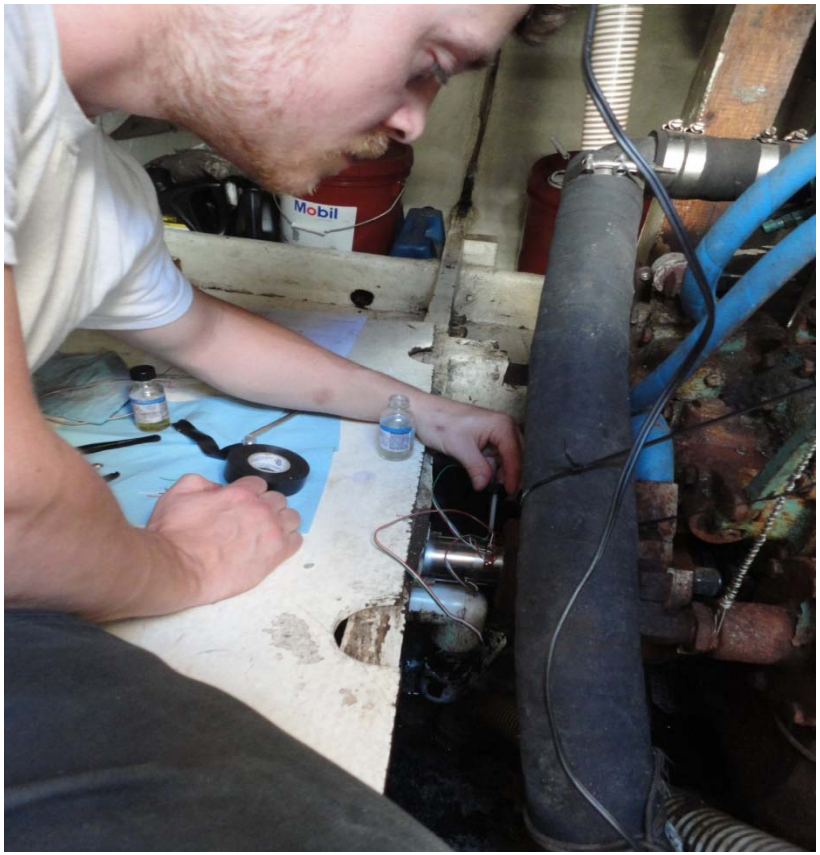


# Torque Meter
# Measuring Engine Shaft Horse Power

Propeller Shaft Power Measurements: **8 Fishing Vessels**



Strain Gauge installed on Shaft




Intern Jacob Installing Strain Gauges on F/V Salty

# Engine Fuel Efficiency

## Brake Specific Fuel Consumption (BSFC)

- Engine Efficiency: Conversion of energy in fuel into useful work
  - Lb of Fuel / HP-hr produced
  - Kg of Fuel/ kWh produced

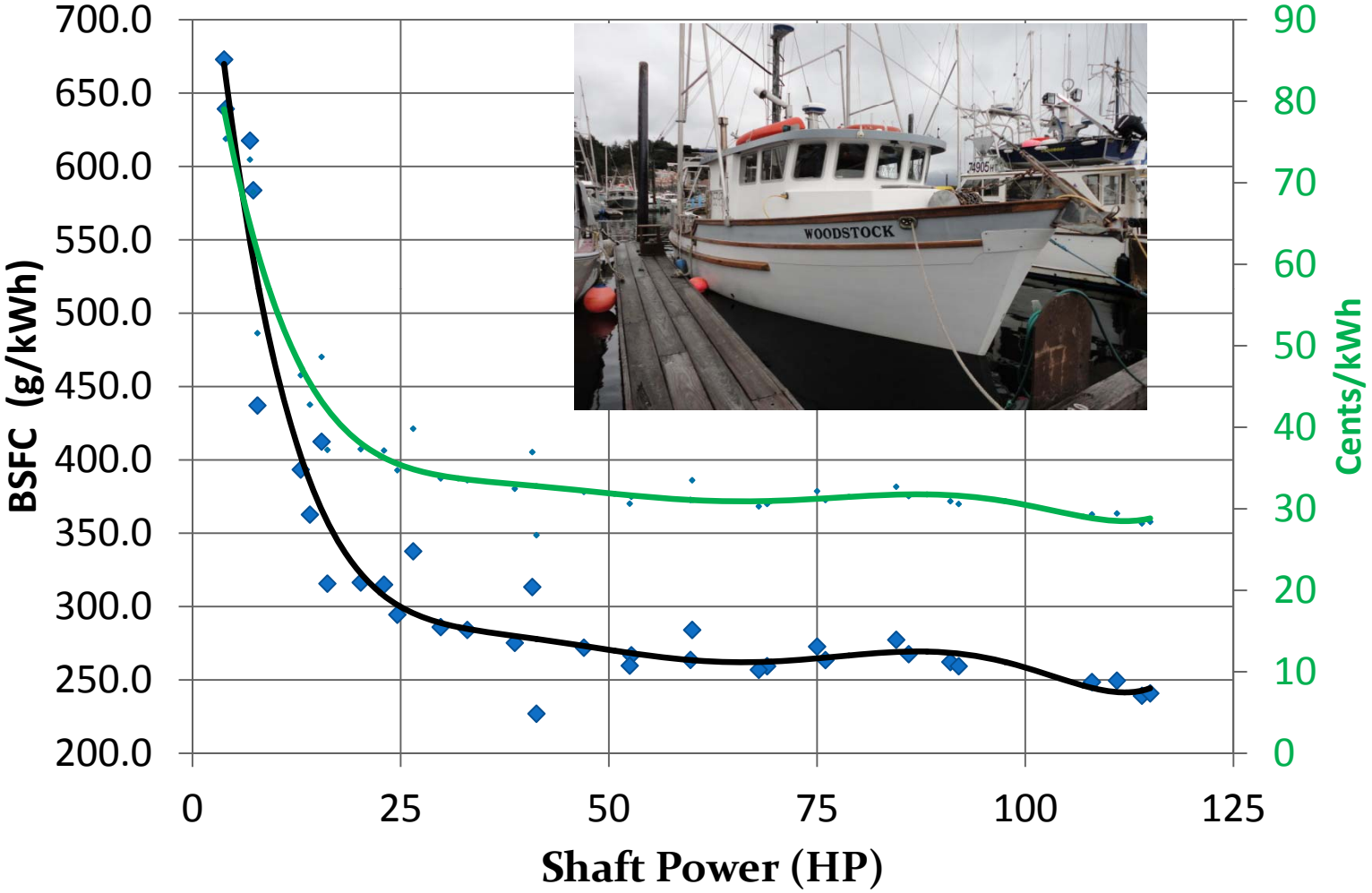
- Factors Effecting BSFC
  - Load on Engine
  - Air Temperature
  - Condition of Engine

# Engine and Vessel Performance Curves




# Woodstock

## 220hp 4 Cycle Cummins NH220



# Woodstock 39’ Power vs. Speed

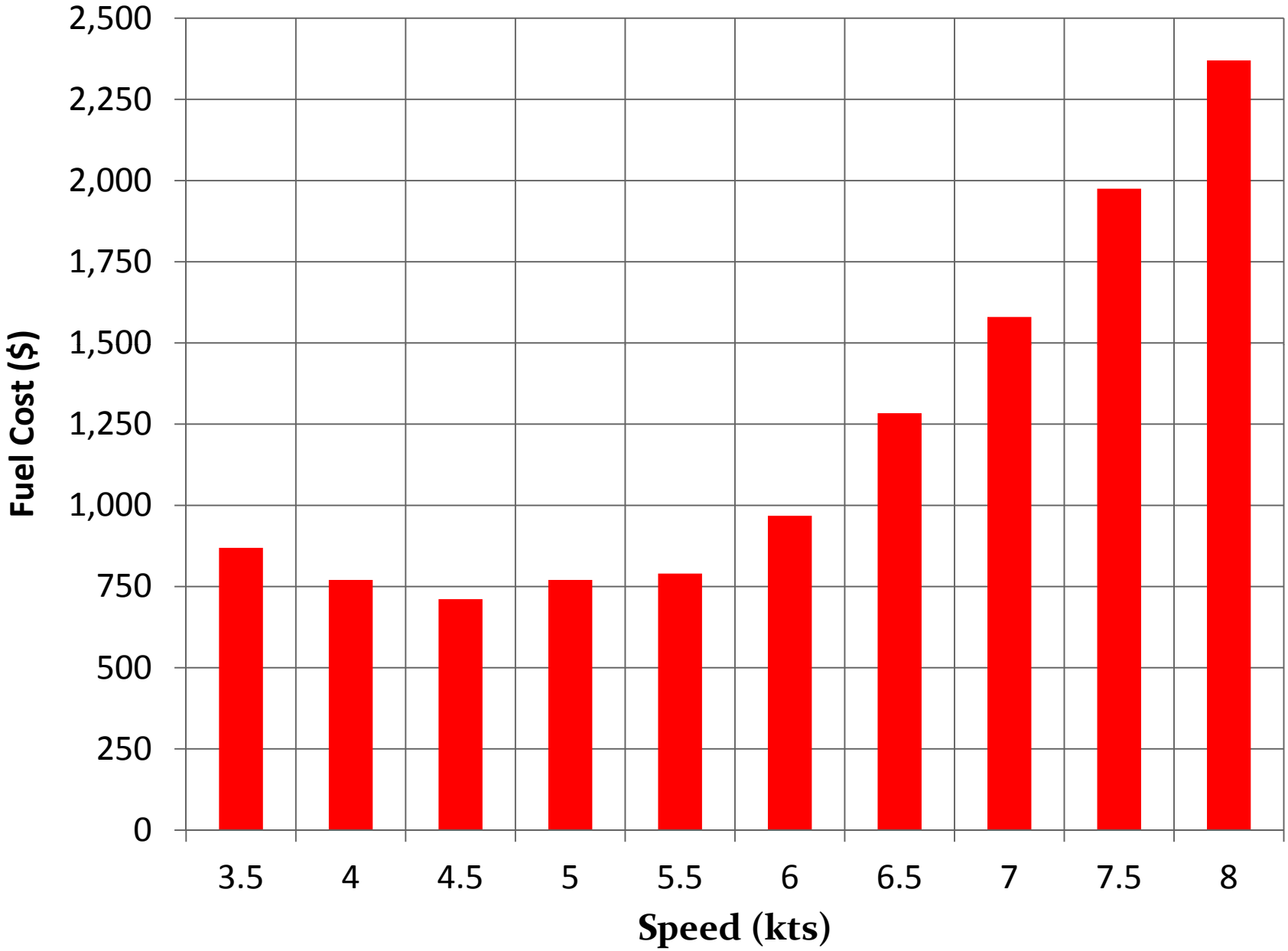

Shaft Power (HP)

140
120
100
80
60
40
20
0

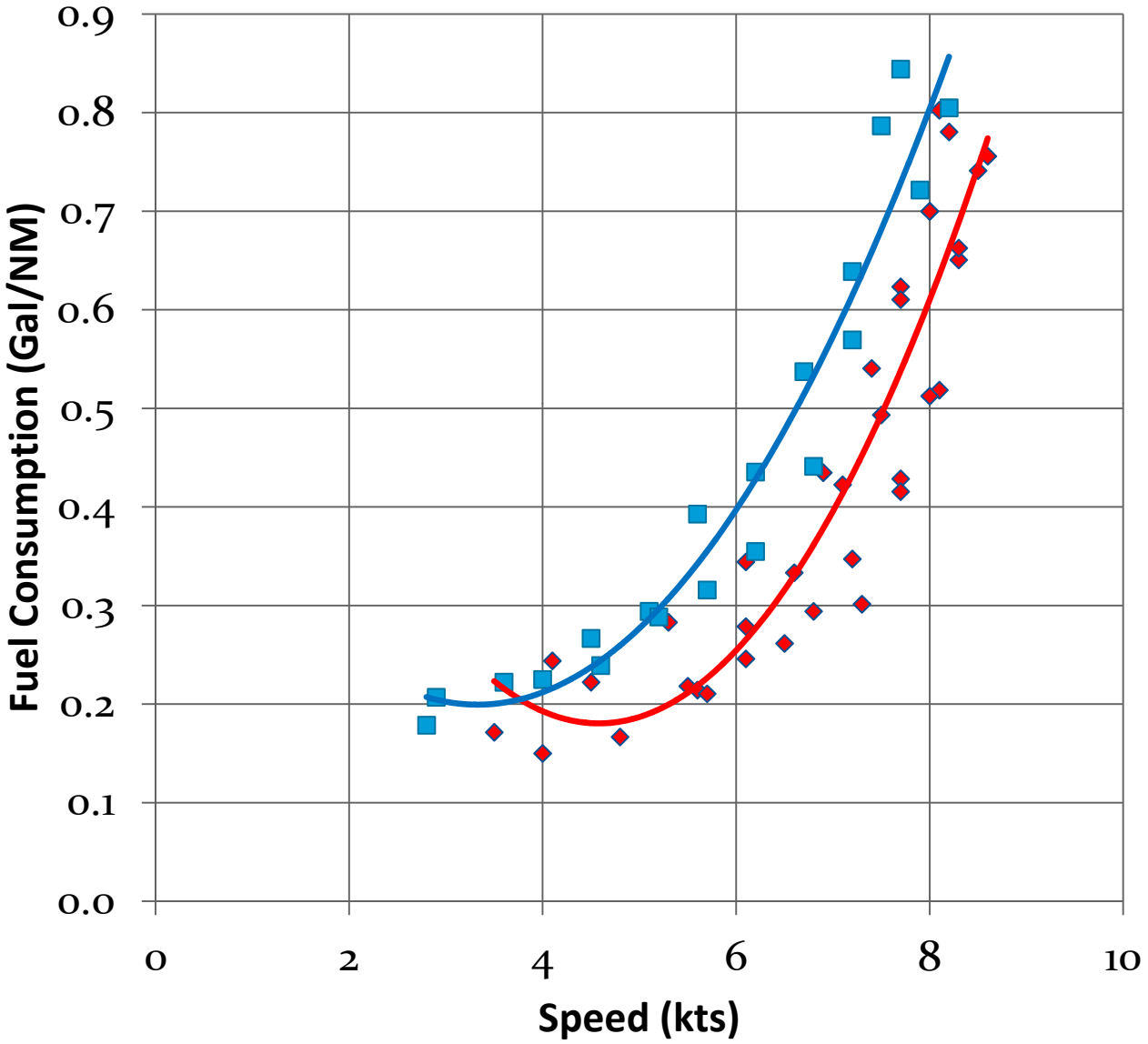
0
2
4
6
8
10

Speed (kts)

# Woodstock Fuel Cost/1,000 miles



# Woodstock, Stabilizer and Fuel Penalty

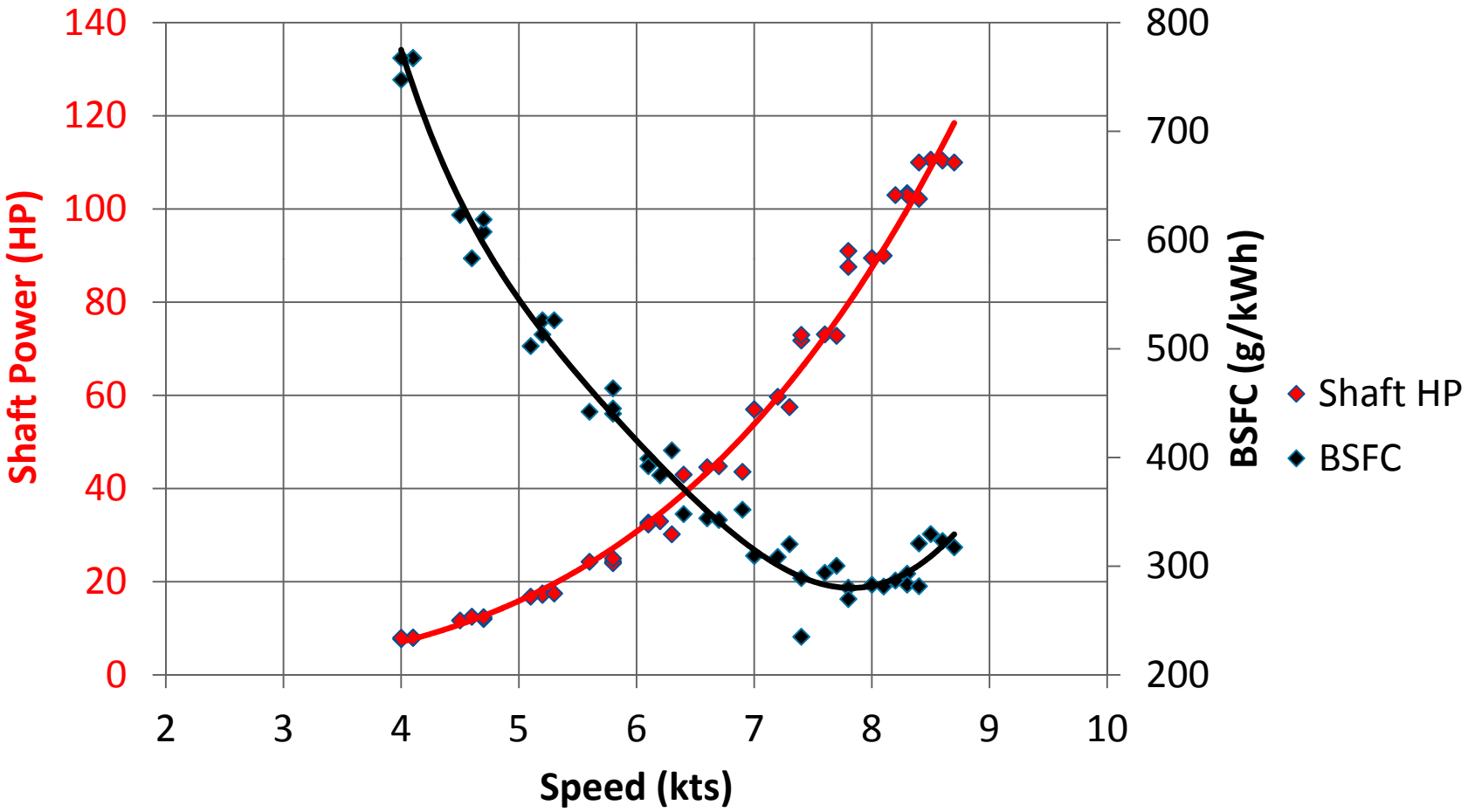



Fuel Cost:
1,000 NM/yr @ 6kts

With: $1,600
Without: $1,000
Difference:$600

- Woodstock no stabilizers
- With Stabilizer

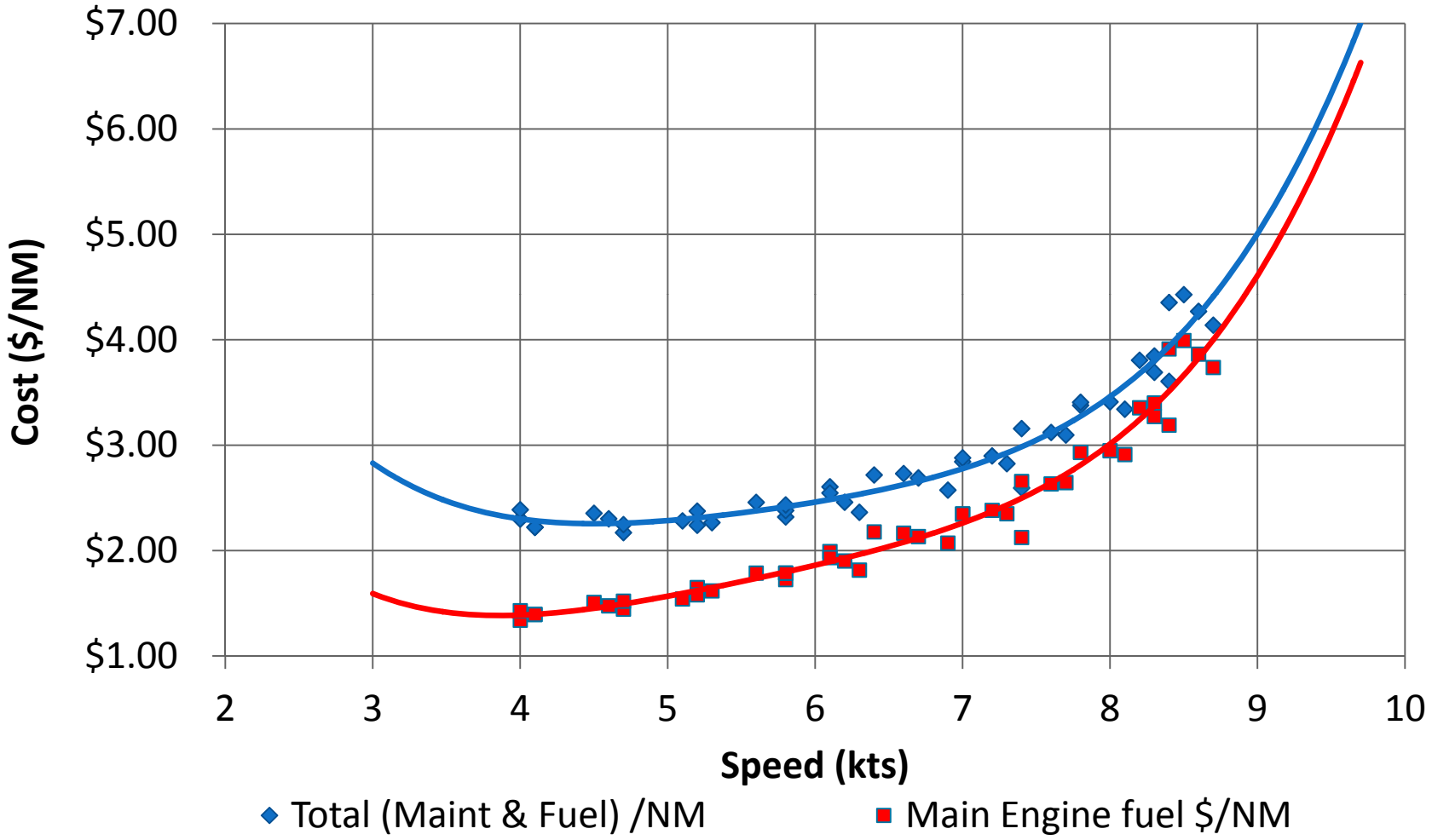
# F/V Myriad
# Speed Efficiency vs. Engine Efficiency




Engine Not Optimized for Normal Operating Speed

# F/V Myriad : Most Economical Speed

## Main Engine Fuel Cost vs. Total Cost




Energy Analysis Tool Includes User Defined Maintenance cost

# Energy Analysis Tool
# F/V Myriad Main Engine Maintenance Input Page

| **#1 Main Engine Maintenance** | Interval (hrs.) | Cost ($) | Hourly Cost $/hr. |
|---|---|---|---|
| | | | |
| Oil Change | 300 | $200.00 | $0.67 |
| Minor Overhaul | 5,000 | $1,500.00 | $0.30 |
| Major Overhaul | 30,000 | $25,000.00 | $0.83 |
| Annual Misc. Repair | 1,200 | $500.00 | $0.42 |
| Other | 0 | $0 | #DIV/0! |
| Other | 0 | $0 | #DIV/0! |
| Total | | | $2.22 |

# F/V Topaz (78’, 1,000 HP): Shaft HP vs. Speed


Shaft Power (HP)

1000
900
800
700
600
500
400
300
200
100
0

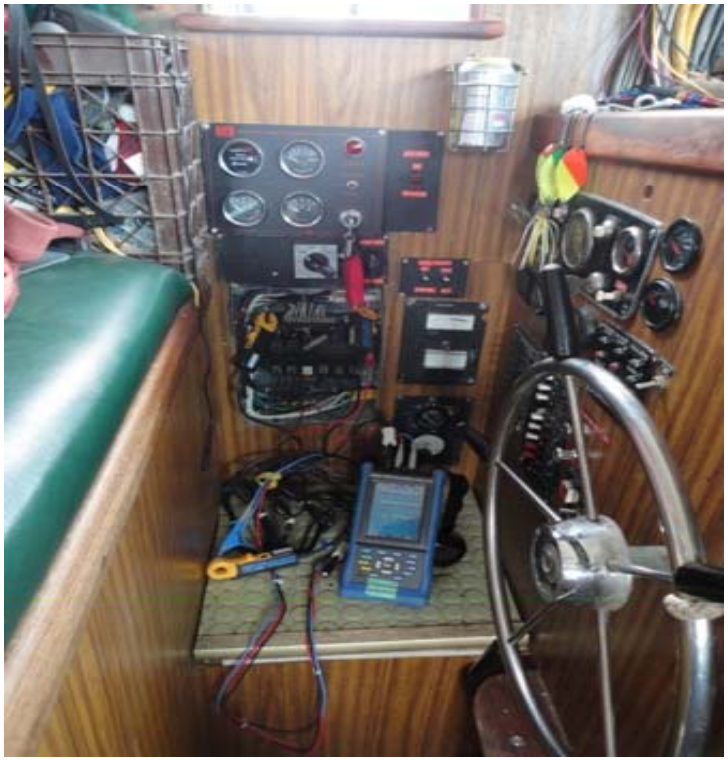
0
2
4
6
8
10
12

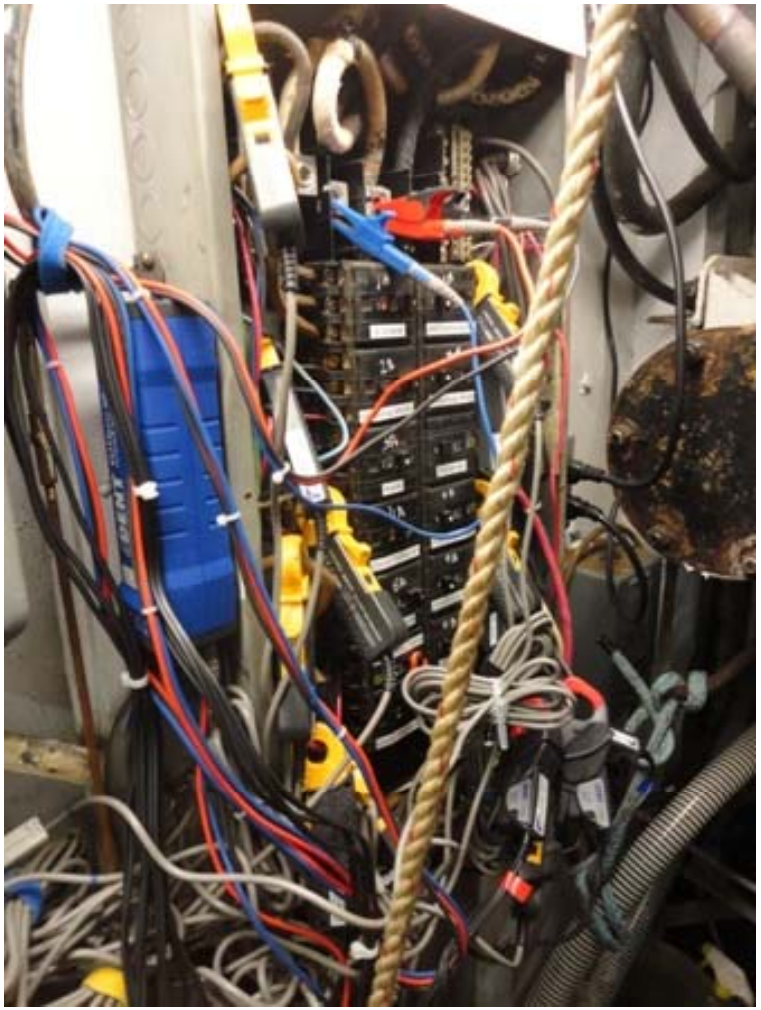
Speed (kts)

# A/C System: Generation and Load

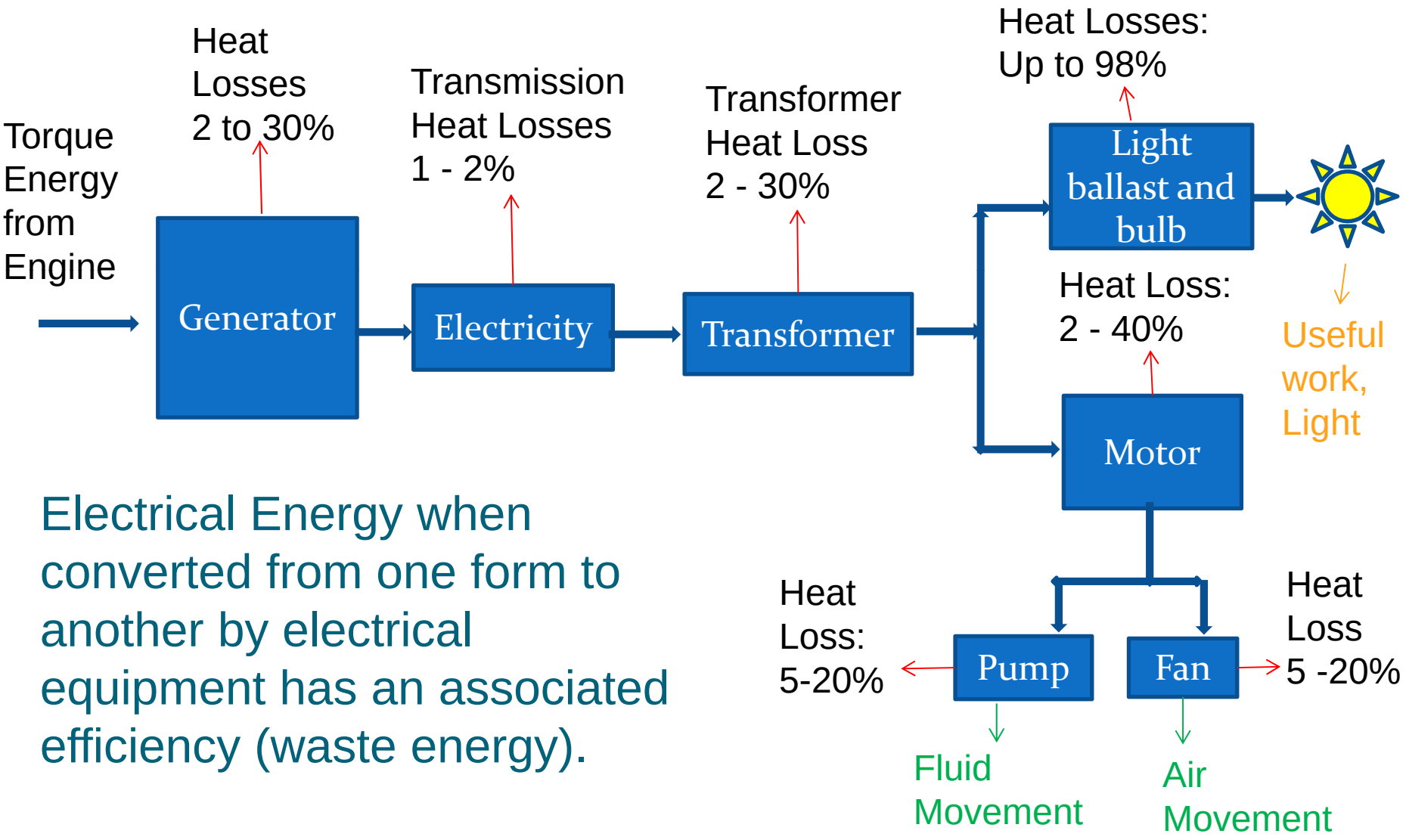
Diesel Generators
Inverters
Loads:

- Motors
- Lights
- Heaters



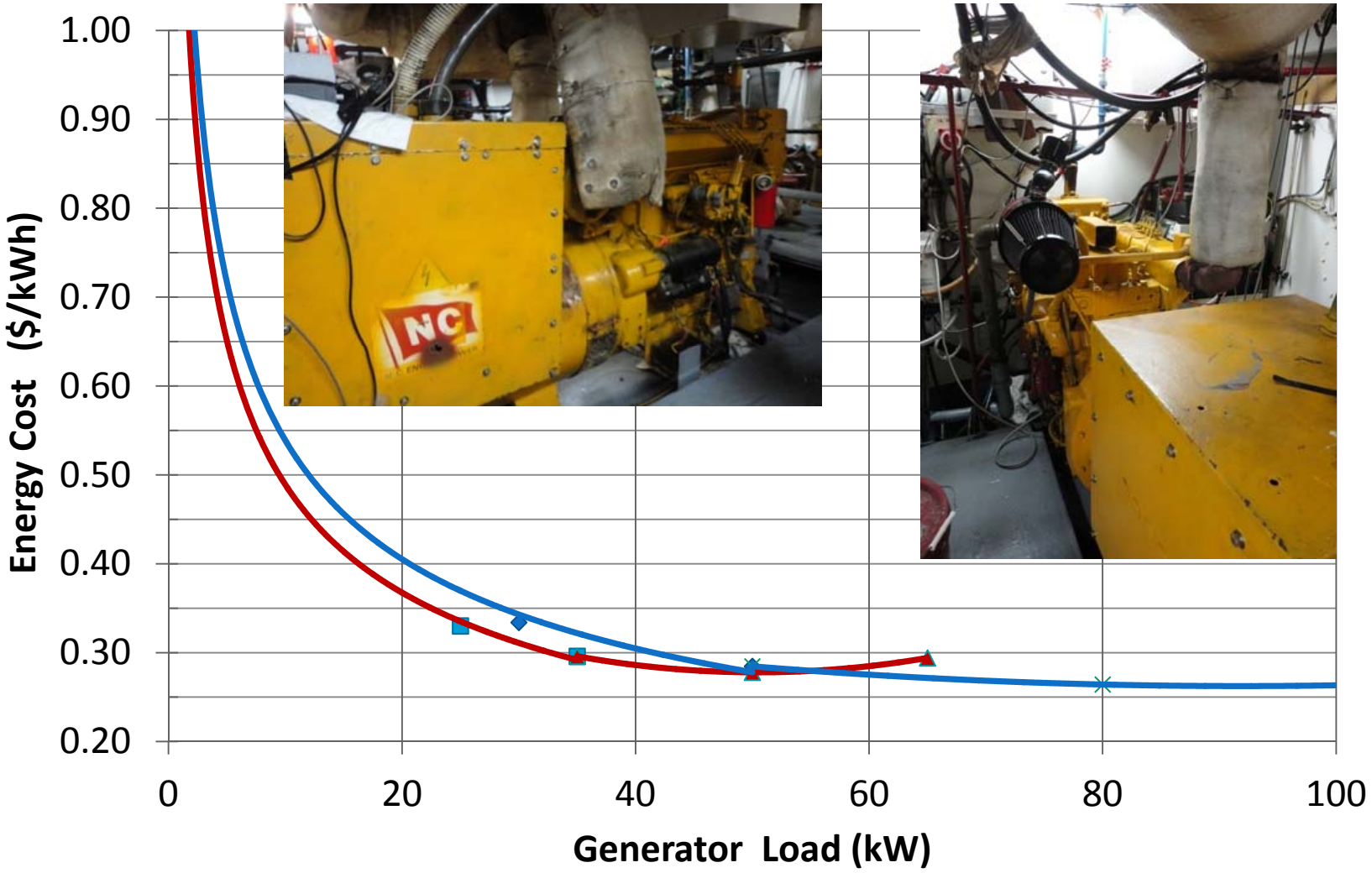


# Electrical Equipment Efficiency

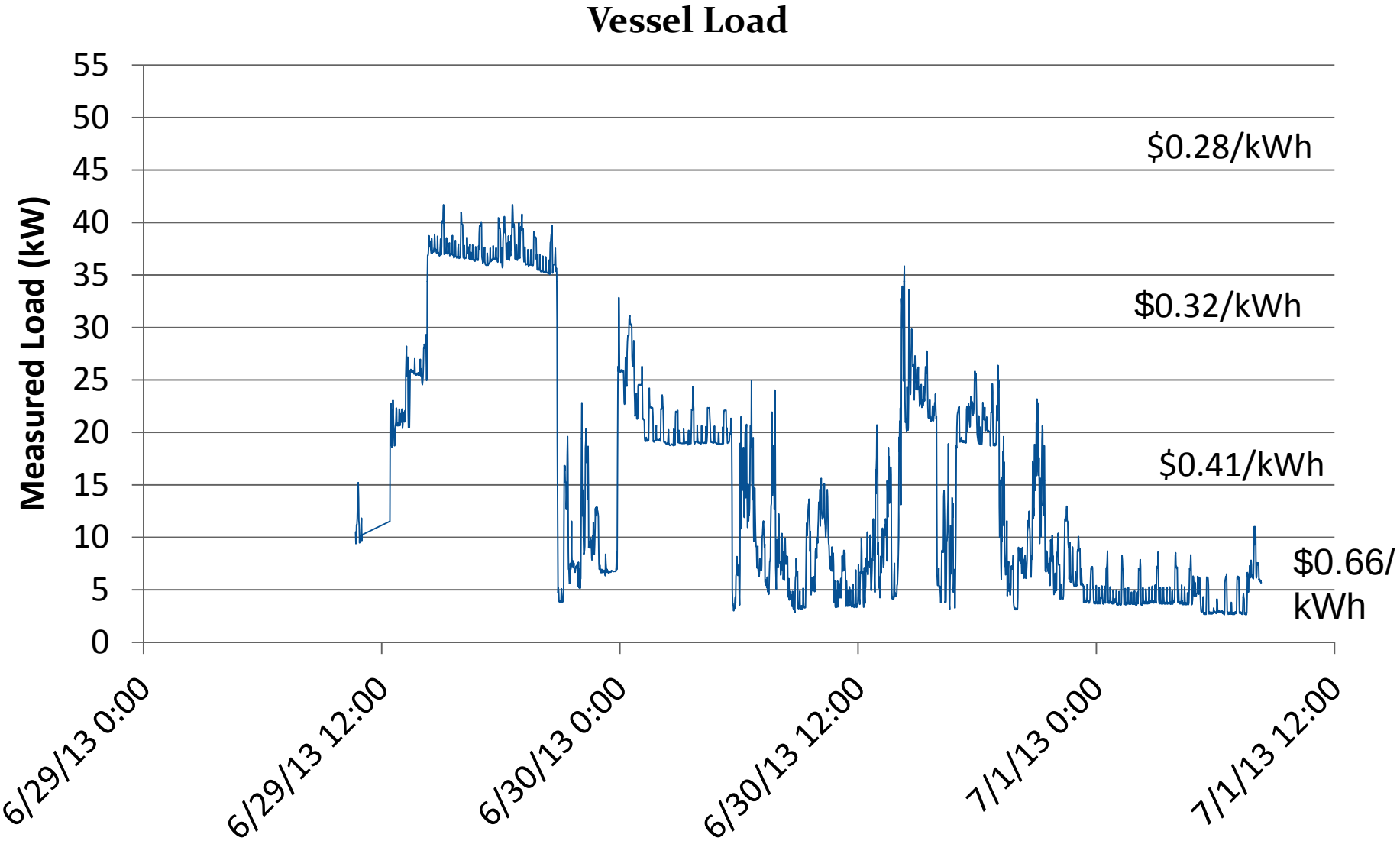



Electrical Energy when converted from one form to another by electrical equipment has an associated efficiency (waste energy).

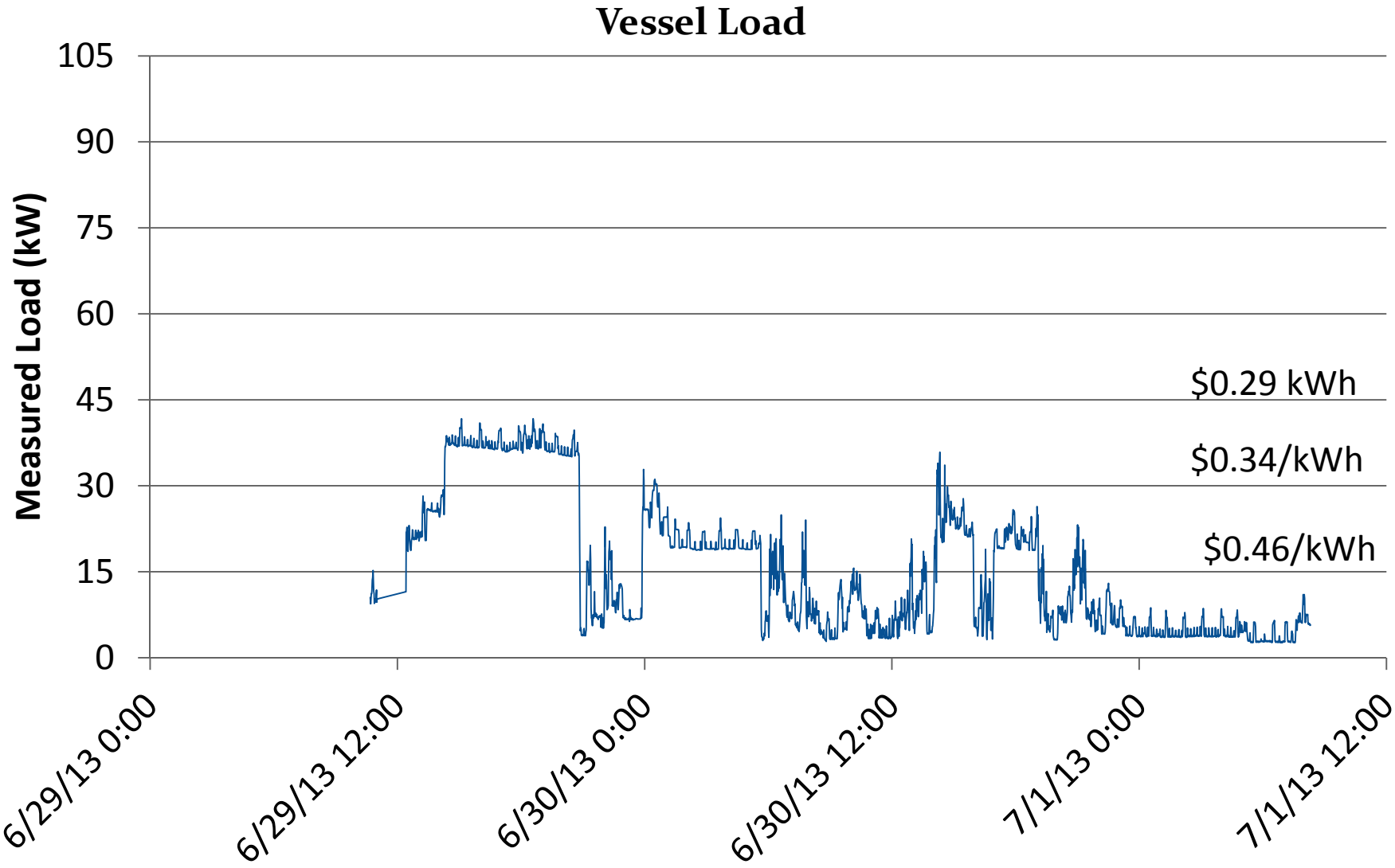
# F/V Savage Aux Power: 105 kW and 55 kW Gensets



# F/V Savage Aux Load 2 day Trip
# 55 KW Cat Genset



# Savage: Aux Load 2 Day Trip
# 105 kW Cat Genset



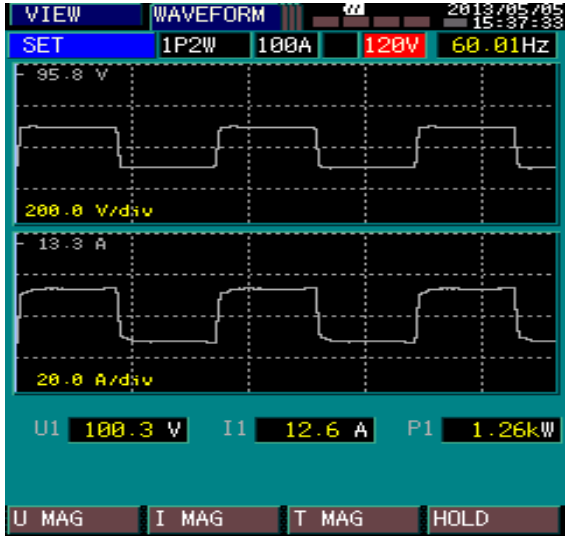
# Engine Efficiency and Costs

| Load (kW) | Annual hours | Cost with 105 kW Engine | Cost with 55 kW Engine | Cost with 55 kW and 10 kW Engines |
|---|---|---|---|---|
| 3 | 3000 | $3,780 | $3,690 | $2,790 |
| 8 | 1750 | $5,460 | $4,900 | $3,780 |
| 20 | 125 | $850 | $750 | $750 |
| 30 | 125 | $1,163 | $1,050 | $1,050 |
| | Total | $11,253 | $10,390 | $8,370 |
| | | | Savings | $2,883 |

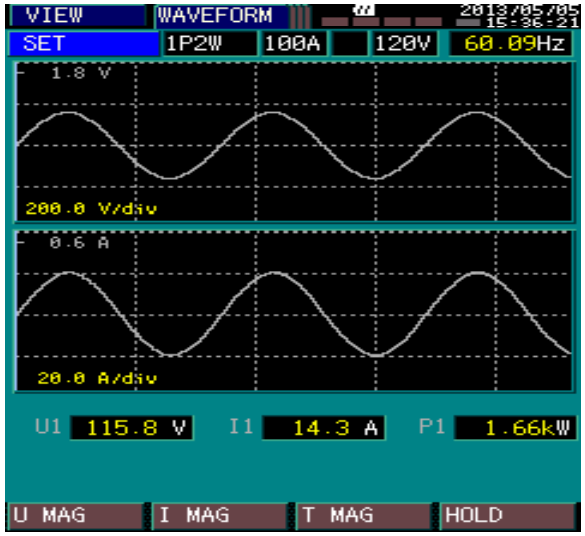
# A/C Power from Inverters

- **Square Wave**
  - Issues with sensitive gear
  - Increases energy consumption
  - Lowest Cost
- **Modified Wave**
  - Less equipment sensitive
  - Better efficiency
  - Modest cost
- **True Sine Wave**
  - No issues with sensitive gear
  - Same or better than shore power
  - Best efficiency for gear
  - Highest Cost

Efficiency and impact on cost example to follow in next section

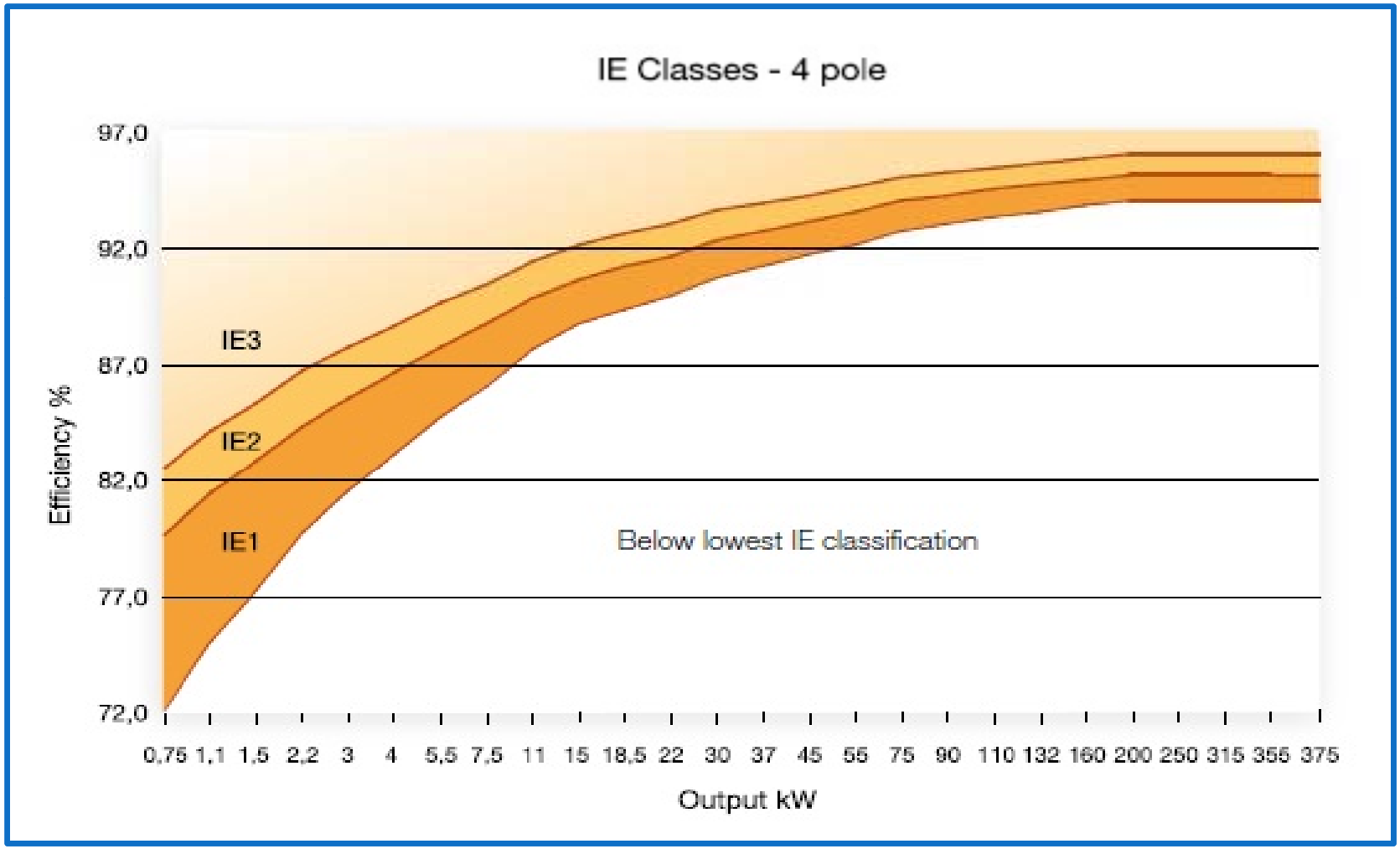



Square Wave Inverter




Shore Power

# Motor Efficiency




http://ngelmuelektro.wordpress.com/2011/06/24/motor-efficiency

# Motor Efficiency and Savings

**88% Standard Efficient Motor** - 15 HP Circulating Pump

Input Power: 17.04 HP

Cost for 2000 hrs/yr (23%) operation**: $8,898**

**92.4% Premium Efficient Motor** - 15 HP Circulating Pump

Input Power: 16.23 HP

Cost for 2000 hrs/yr (23%) operation: **$8,475**

**Annual Savings: $423/yr**

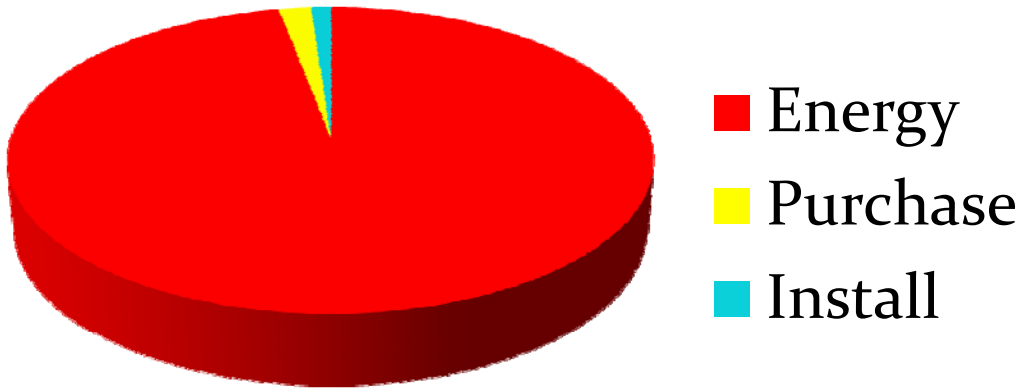
Initial Cost: $1,600

Motor Life: 10 yrs

Annual ROI: 16.4%

Payback: 3.78 yrs

**10 Year Motor Life Cycle cost**



# Motor Efficiency and Savings

**68% Standard Efficient Motor** - 1 HP Circulating Pump

Input Power: 1.47 HP
Cost for 2000 hrs/yr (23%) operation: **$768**
Purchase Price: $321

**82.5% Premium Efficient Motor** - 1 HP Circulating Pump

Input Power: 1.21 HP
Cost for 2000 hrs/yr (23%) operation: **$626**
Purchase Price: $446

**Annual Savings: $141/yr**
Cost Difference: $125
Motor Life: 10 yrs
Annual ROI: 102.7%
Payback: .89 yrs

http://www.baldor.com/products/

# MOTORS CONTROL

Motor Variable Frequency Drives (VFD) Steering Gear, Fans, Pumps, Winches

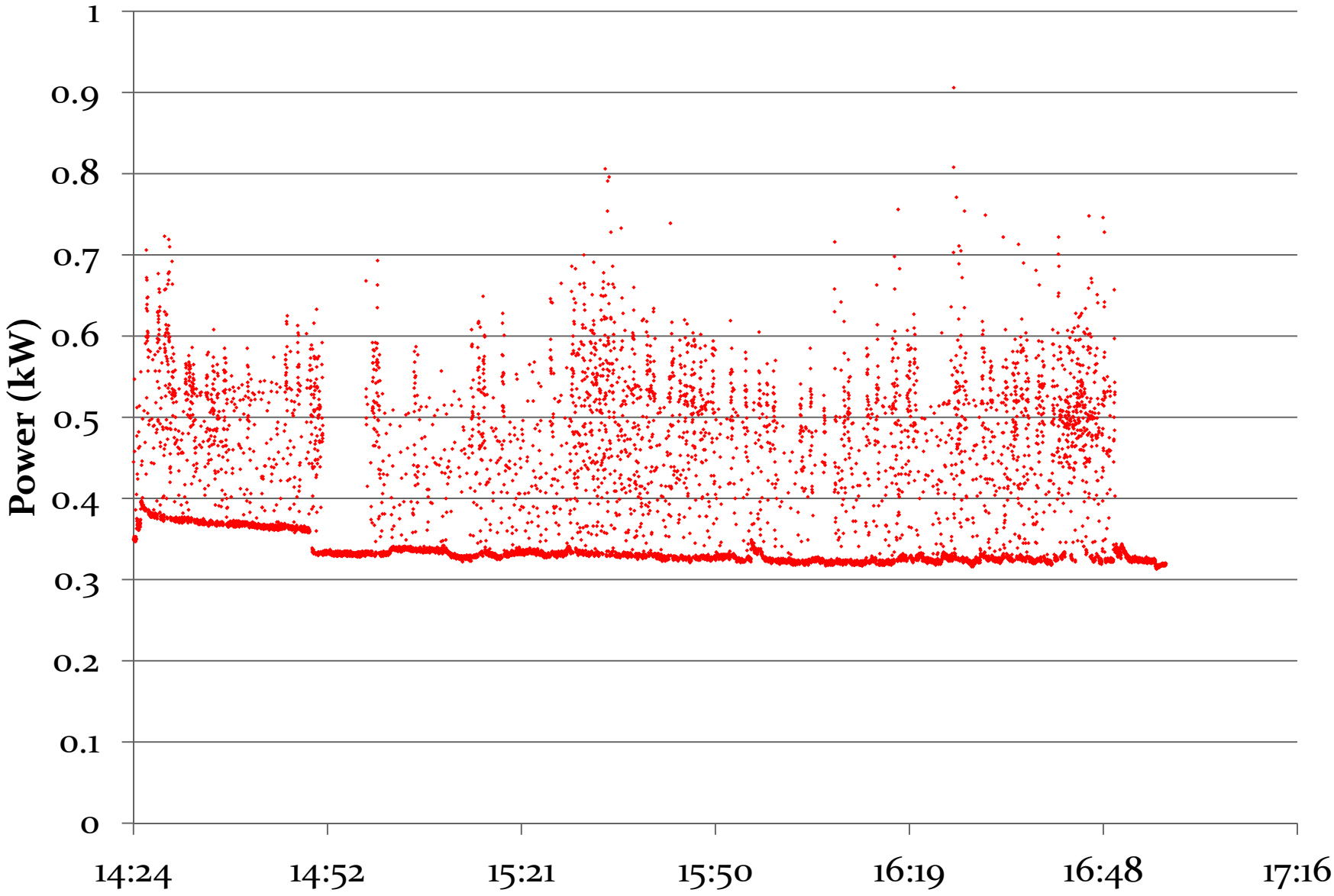
VFD for S.W. Cooling Pump

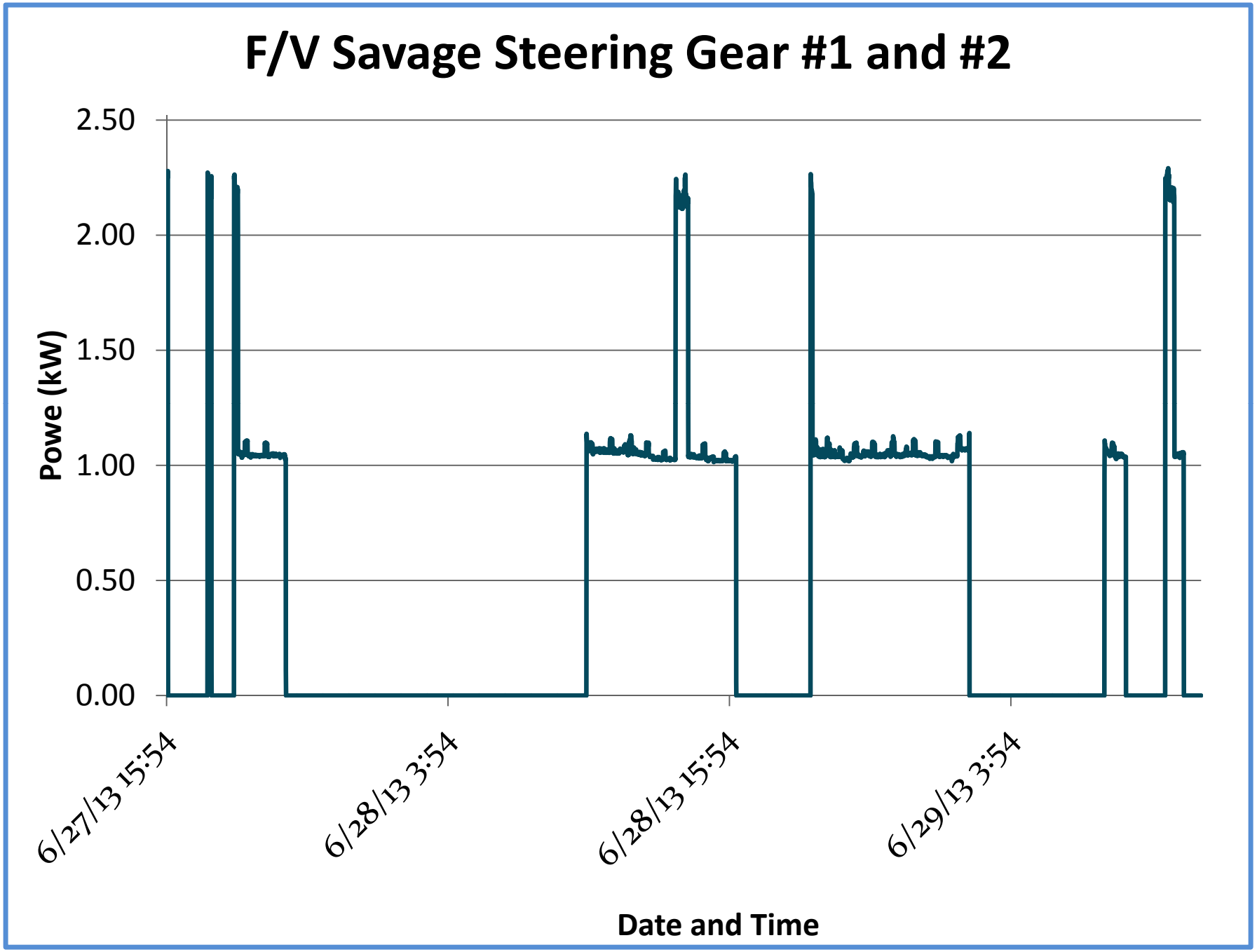
Reduce Centrifugal Pump Speed by ***½***

=

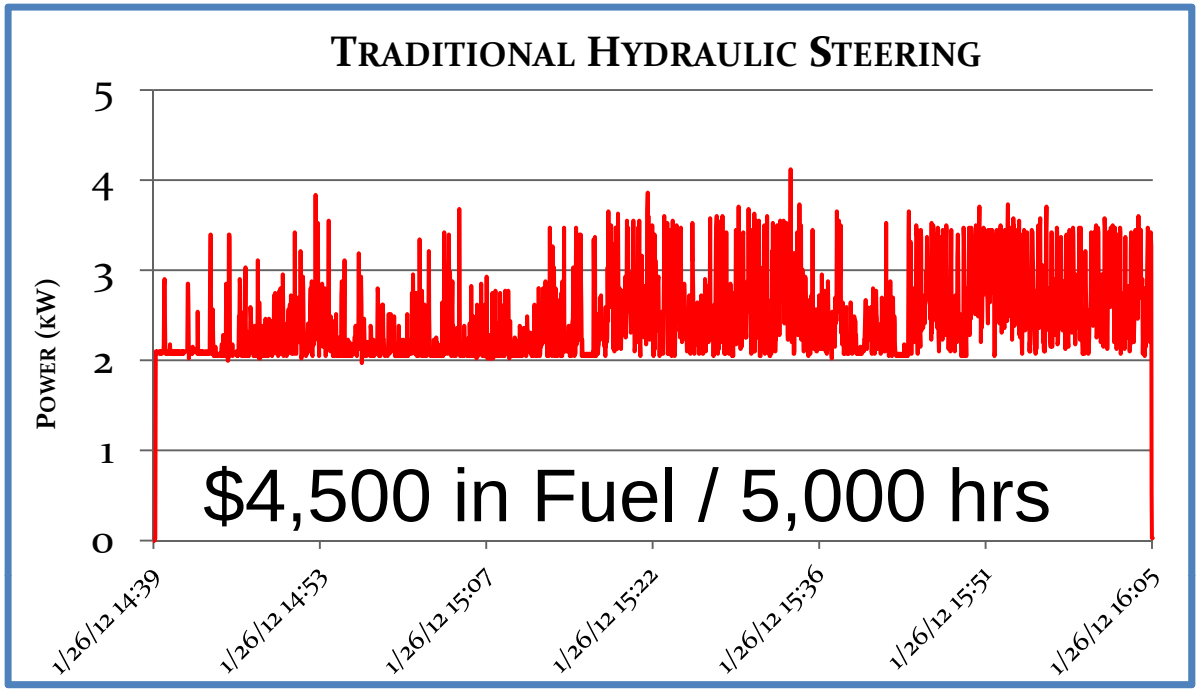
Power and Fuel Consumption reduced to ***1/8***

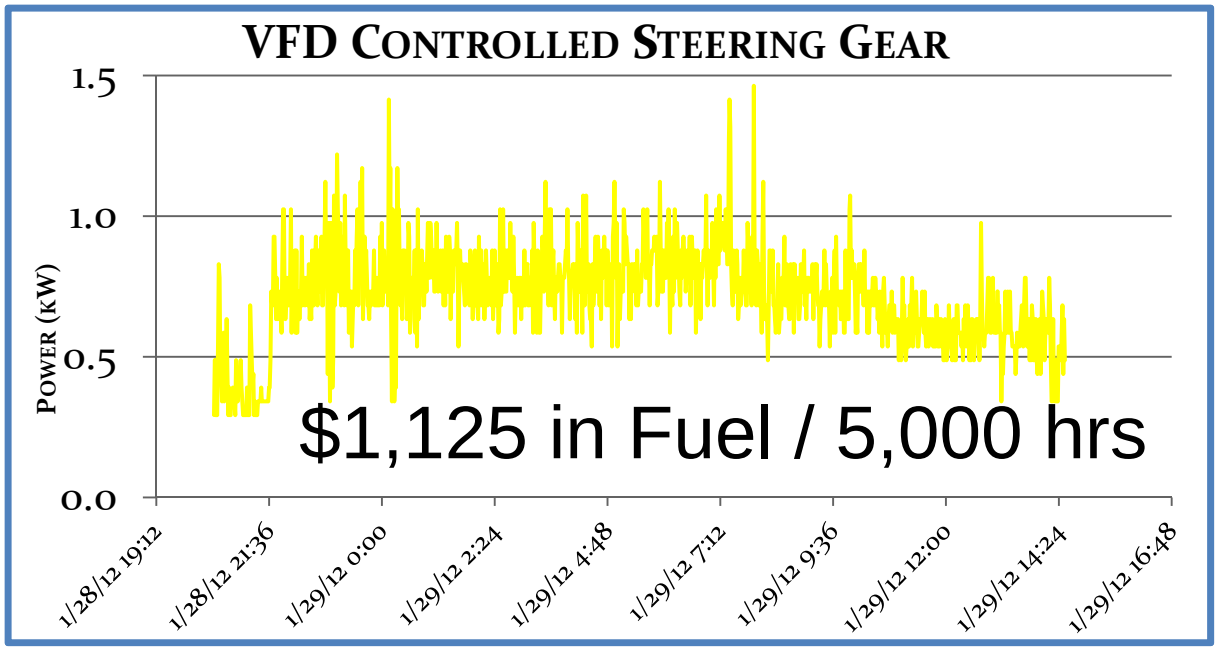
# F/V Topaz Steering Gear




F/V Savage Steering Gear #1 and #2
2.50
2.00
1.50
1.00
0.50
0.00
Powe (kW)
6/27/13 15:54
6/28/13 3:54
6/28/13 15:54
6/29/13 3:54
Date and Time

VFD on Hydraulic Steering
70% Reduction in Energy Usage



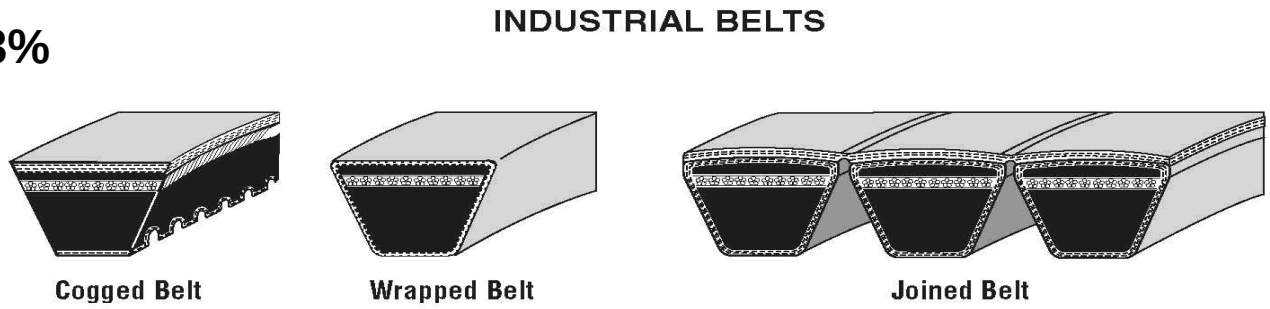



# DC Power Generation

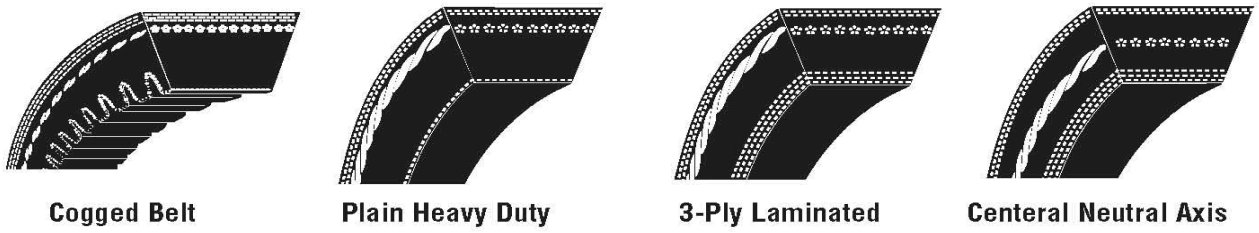
Alternator
and
Drive Belt
Efficiency

# DC Power Generation
# Belt Losses: Engine to Alternator

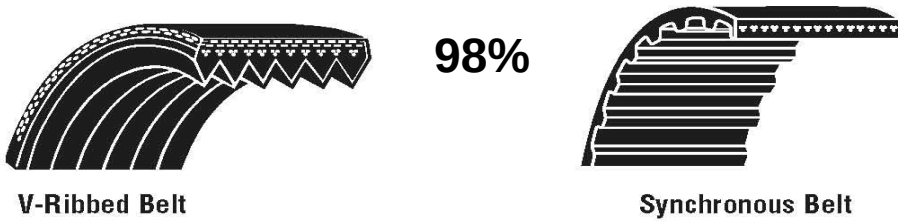
**93%**




**95%**




**98%**



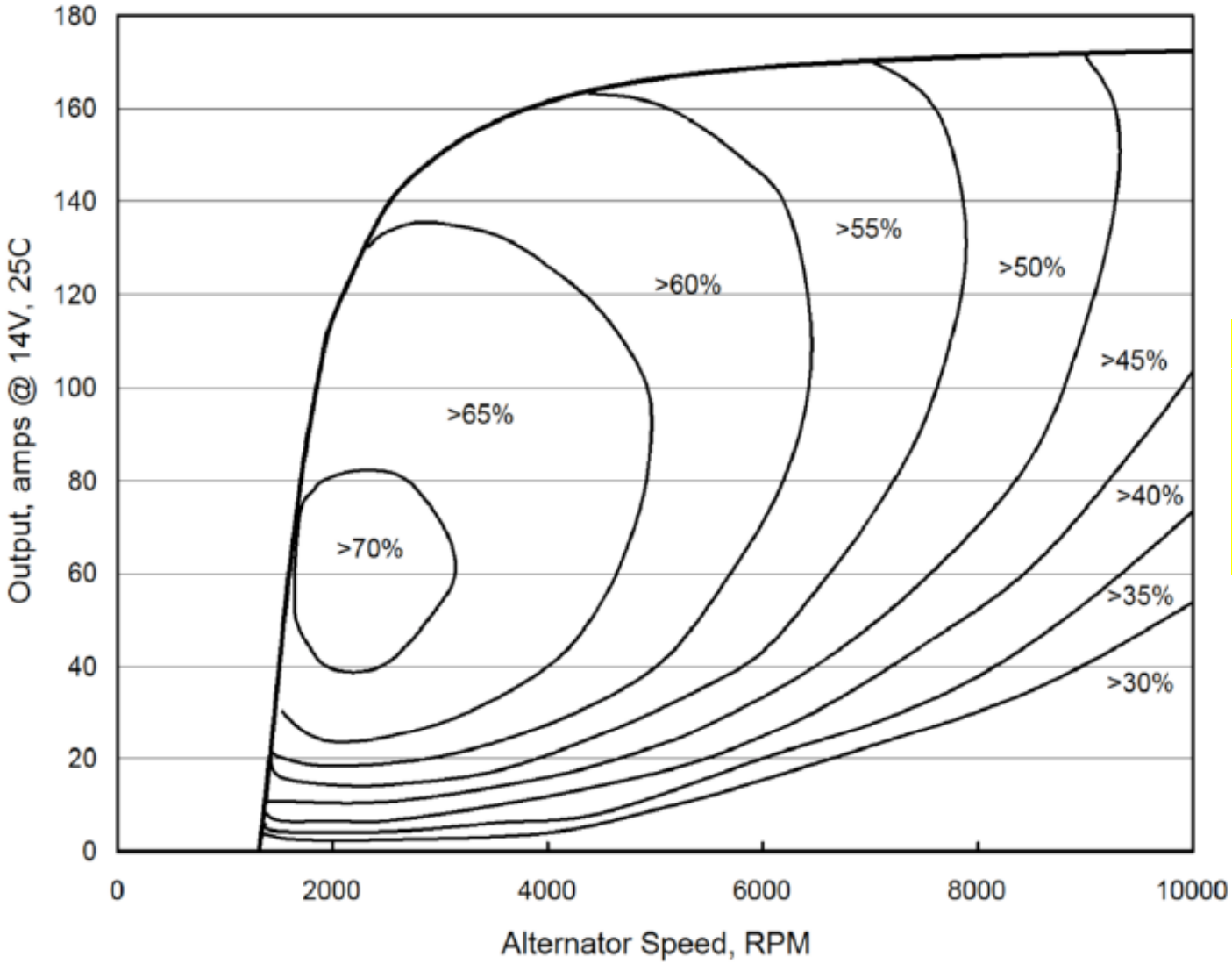

Efficiency Varies by:

- Belt Type
- Tension
- Pulley Size

- Slippage decrease efficiency ~5%

Energy Loss and Efficiency of Power Transmission Belts, Third World Energy Engineering Congress, The Association of Energy Engineers

# Alternator Efficiency: Load and Speed




Properly Size Alternator

White Paper: Improving Alternator Efficiency Measurably Reduces Fuel Cost:
Mike Bradfield, MSME, Remy Inc

# DC System
# Alternator Efficiency: 45% to 85%

DC Load: Ave. **800 Watts**
Hours Fishing and Transit = 1,549 hrs
Engine BSFC 228 g/kWh = $0.29/kWh
Fuel Cost before Alternator Losses:
$360

Alternator input power for 800 Watt:
45% Efficient: **1,778 Watts**
85% Efficient: **941 Watts**


Baseline From McCrea Energy Analysis Tool

# DC Generation Efficiency Comparison

McCrea DC Load from Energy Analysis Tool: Ave 800W
Hours Fishing and Transit = 1,549
**Energy Cost: Engine BSFC 228 g/kWh = $0.29/kWh**
**Fuel Cost before  without Losses: $360**

Engine Power  to Belt Drive 45% Efficient Alternator (1,775 W)
V Belt 90% Efficiency: 1,976 W
**Fuel Cost: $857**
**Energy Cost: $0.69/kWh**

Engine Power to Belt Drive 85% Efficient  Alternator (941 W)
Synchronous Belt 98% Efficiency: 960 W
**Fuel Cost: $408**
**Energy Cost: $0.32/kWh**

Savings with Efficient Equipment: $449/year

# Inverter Efficiency

Comparison: : Fuel cost for 1,000 Watt (1 kW) load for 1,000 hrs being charged by alternator on engine

Older 80% efficient Inverter

DC Input Power : 1,250 Watts
Engine Power (Alternator Efficiency 50%): 2,500 Watts
Total Efficiency: 40%
$/kWh fuel cost with engine at $0.40kWh **= $1.00 kWh**
**Total Fuel Cost: $1,000**

New 95% efficient inverter:

DC Input Power: 1,052Watts
Engine Power (Alternator Efficiency 70%): 1,502 Watts
Total Efficiency: 66%
$/kWh cost with engine at $0.40kWh = **$0.60 kWh**
**Total Fuel Cost: $600**

Low Loaded diesel Genset:

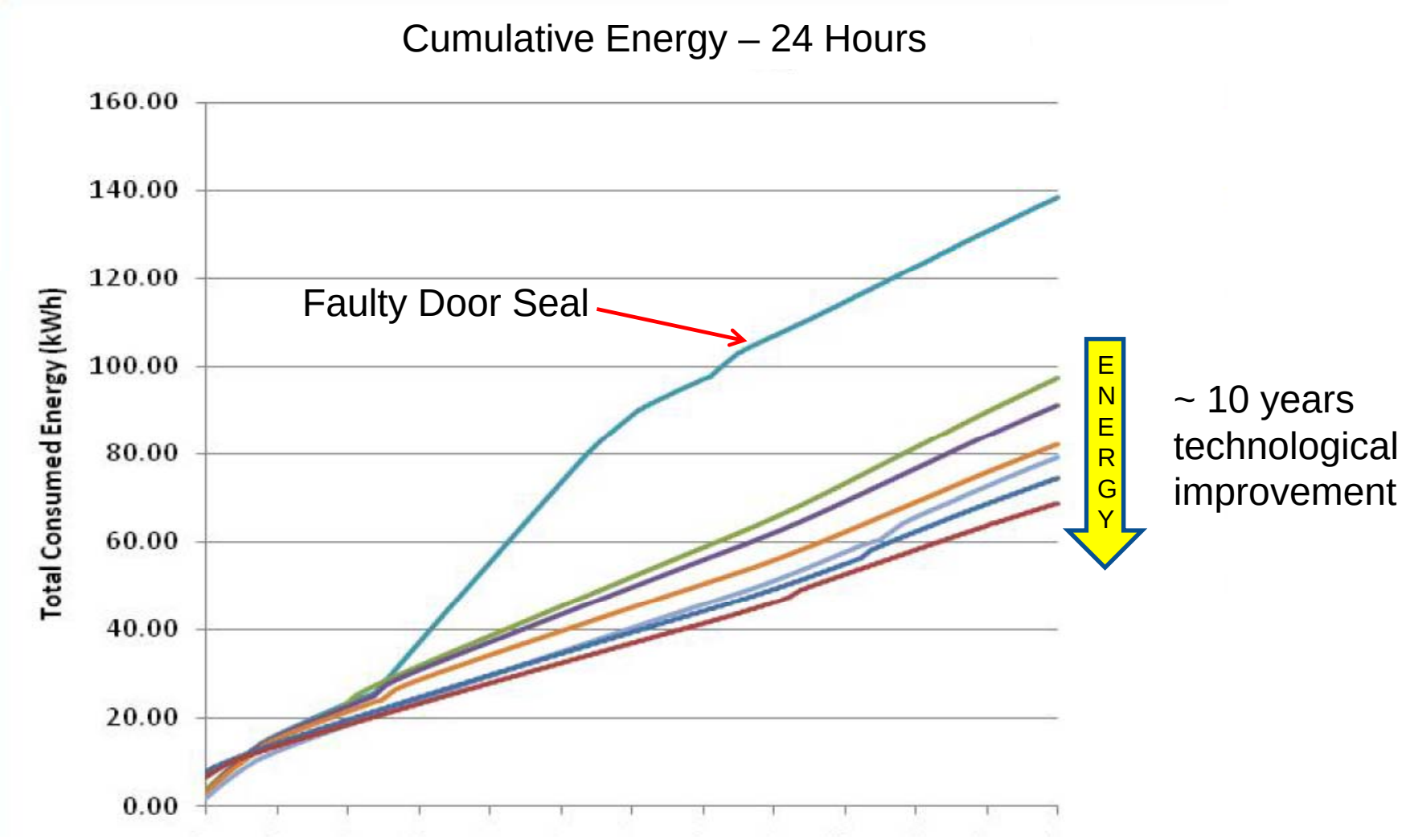
$.90/kWh and Up plus Maintenance ($1.50/hr to $2.25/hr): **$2.40.kWh**
**Total Fuel and Maintenance = $2,400 to $3,150**

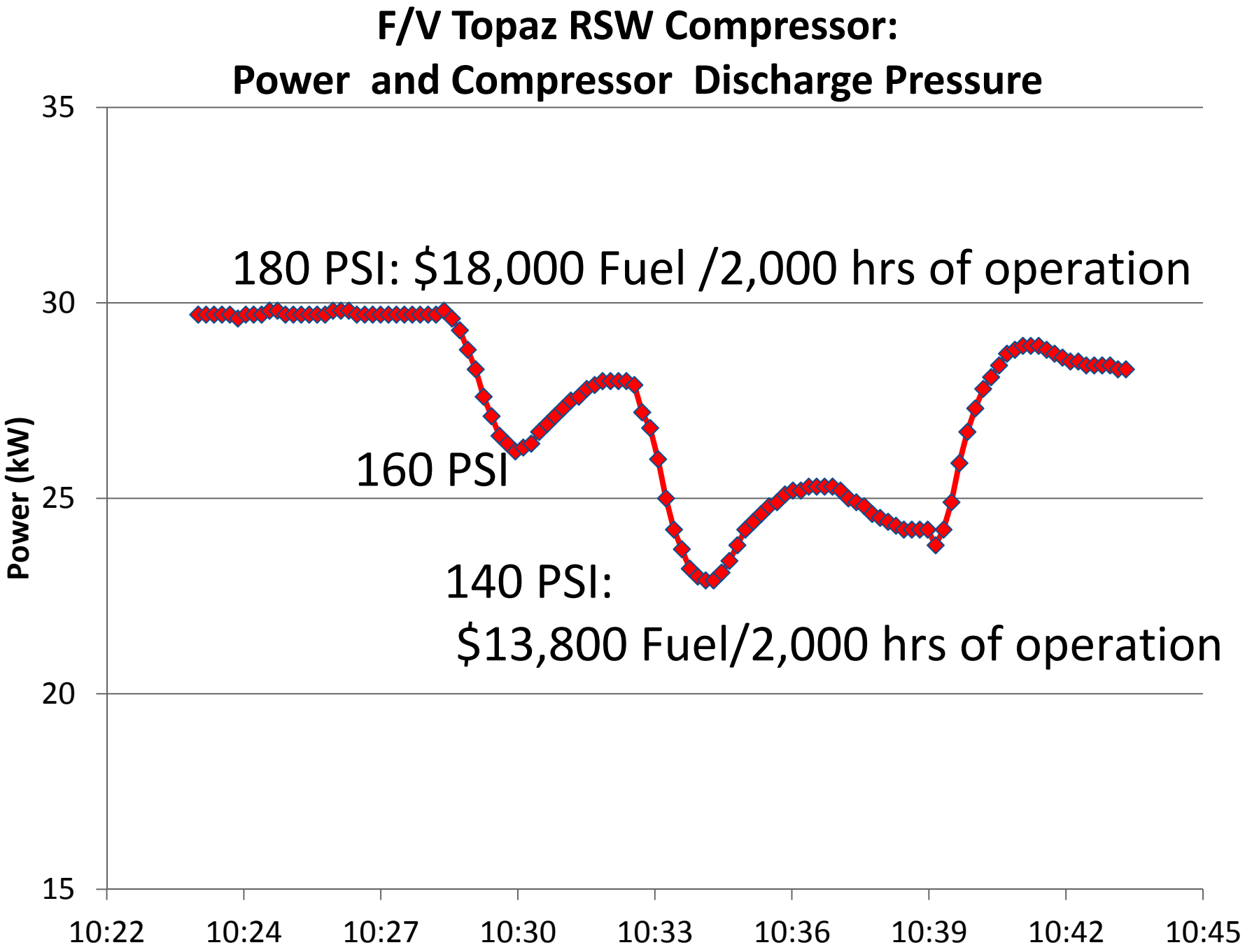
# Refrigeration System

- Compressor Efficiency
- Maintenance
- Operating Pressure

F/V Born Again

# *Maintenance vs. Technology*
# *Compressor Power on Reefer Containers*



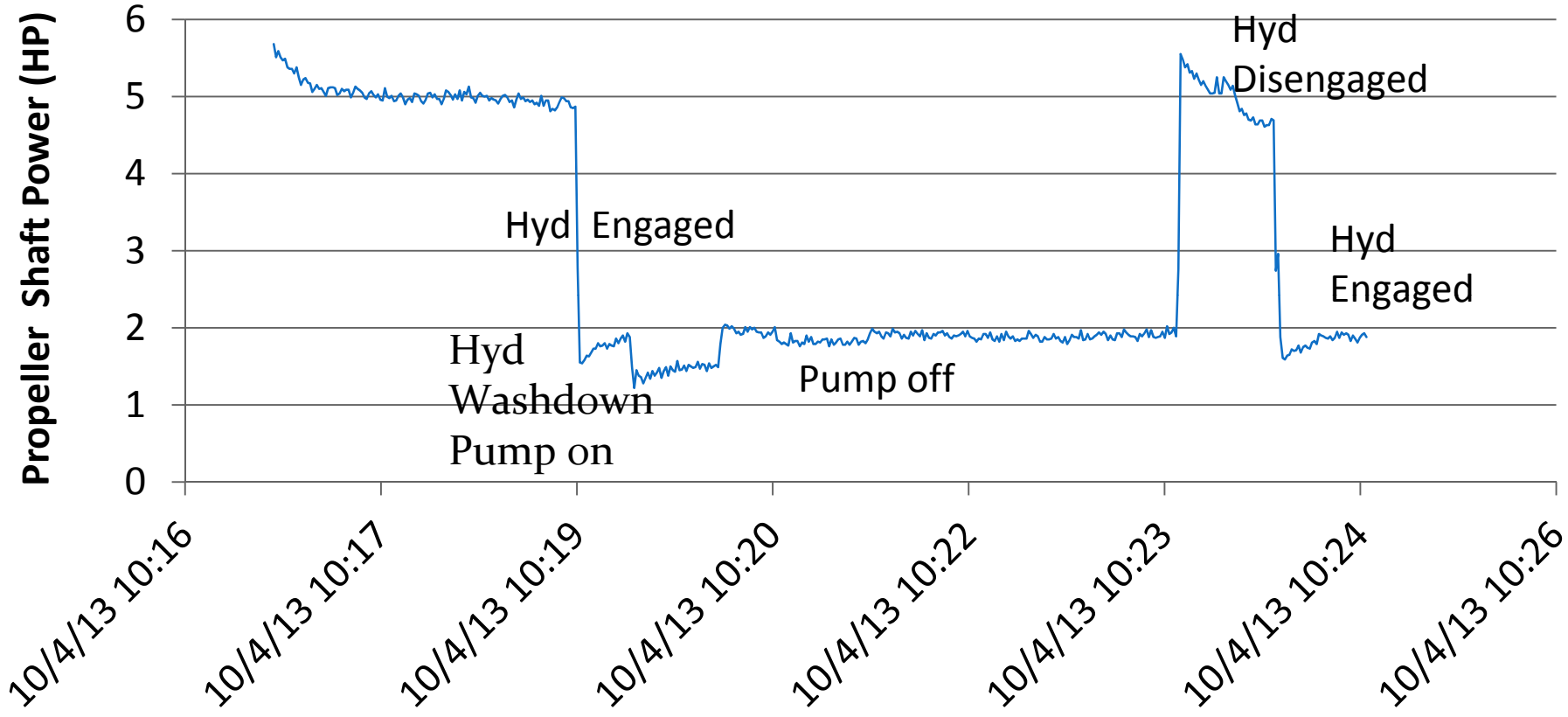

F/V Topaz RSW Compressor:
Power and Compressor Discharge Pressure
Power (kW)
35
30
25
20
15
10:22
10:24
10:27
10:30
10:33
10:36
10:39
10:42
10:45
180 PSI: $18,000 Fuel /2,000 hrs of operation
160 PSI
140 PSI:
$13,800 Fuel/2,000 hrs of operation

# Hydraulic Systems

- Efficiency
- Viscosity
- Cleanliness

El Rio: Belt Driven Engine Mounted Hydraulic Pump

# Hydraulic Systems
# F/V McCrea




Engaged Hydraulic System Losses Produces 2.24 kW of Waste Heat

# Hydraulic Systems: F/V Myriad

| Activity | Measured Fuel (GPH) | Change (GPH) |
|---|---|---|
| Trolling with hydraulics OFF | 1.47 | |
| Trolling with hydraulics ON | 1.68 | -0.22 |
| Trolling while Running Gear w Hydraulics | 1.74 | -0.27 |

| Operating Mode | Name (eg. Ice troll, gillnet, family outing) | Propulsion Engine #1 | |
|---|---|---|---|
| | | Hrs Transit | Hrs Fishing |
| 1 | Longline | 125 | 160 |
| 2 | Ice troll | 70 | 150 |
| 3 | Freeze troll | 160 | 480 |
| 4 | family | 40 | 20 |
| **Total** | | **395** | **810** |

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

# Thank You!

# Back Up Slides

# Radio: HP vs. Speed

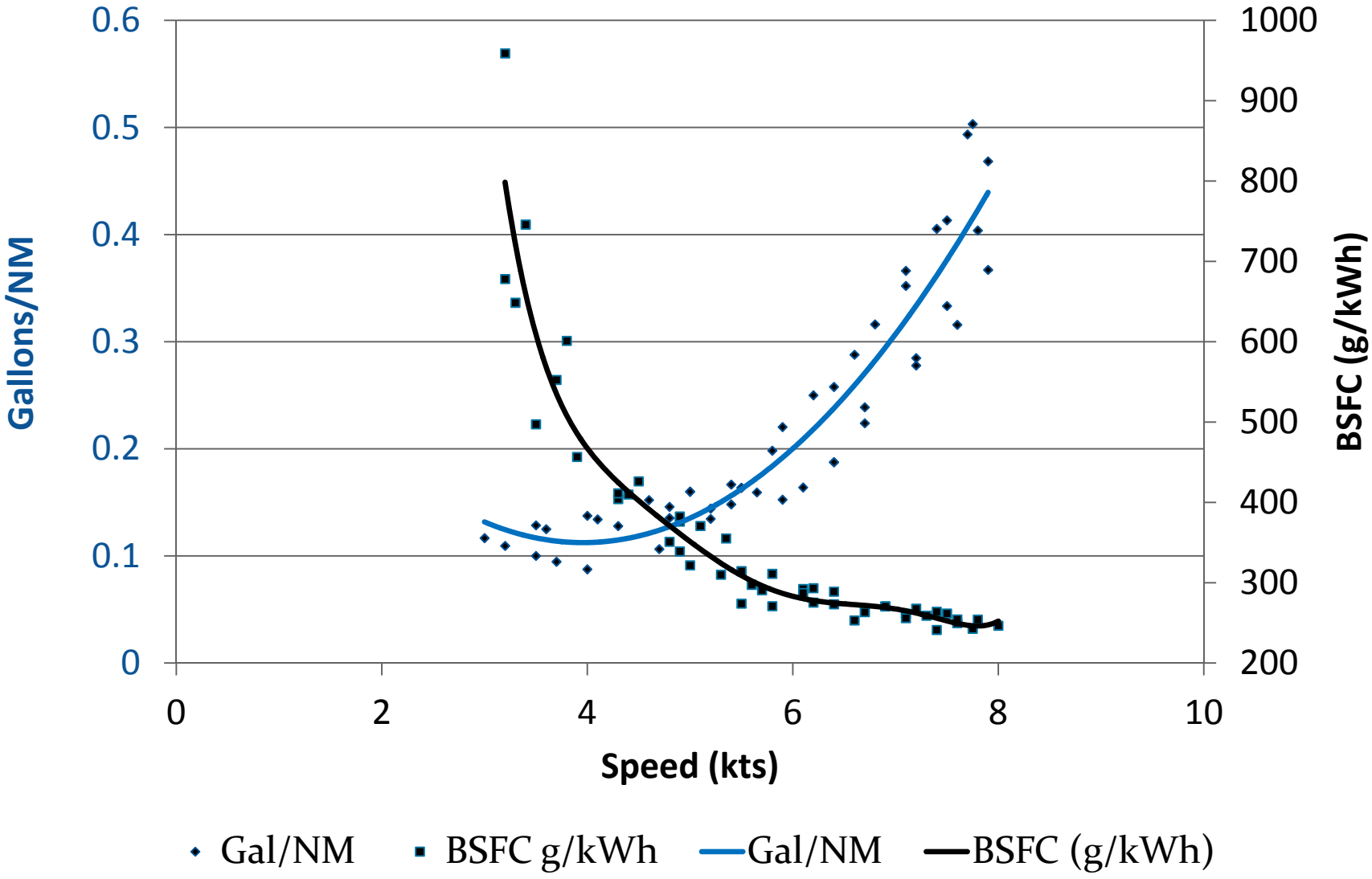

Shaft Power (HP)

80
70
60
50
40
30
20
10
0

0 1 2 3 4 5 6 7 8

Speed (kts)

# F/V Radio
# Speed Efficiency vs. Engine Efficiency



# F/V Savage: Shaft HP vs. Speed

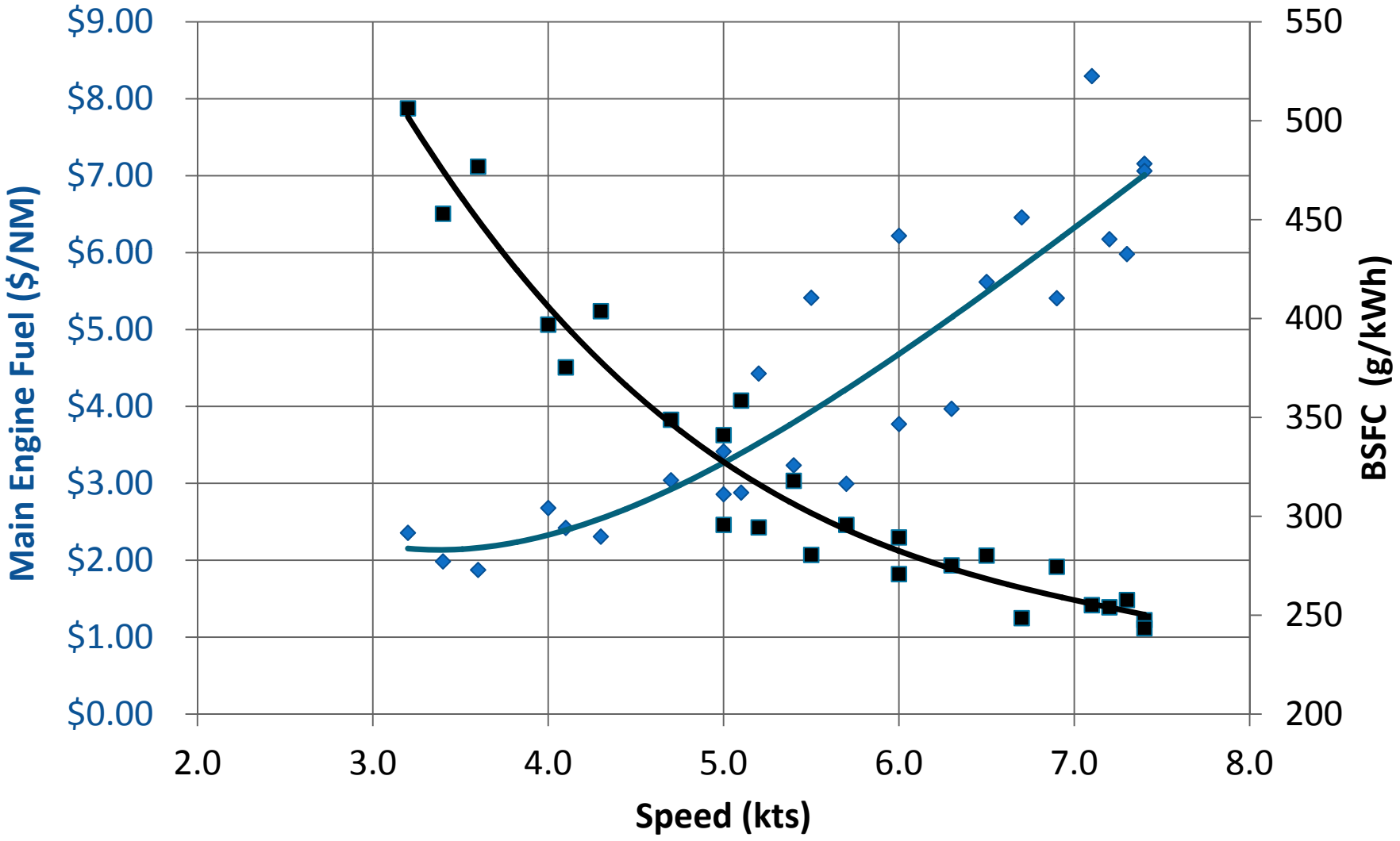

Total Shaft Power (HP)

325
300
275
250
225
200
175
150
125
100
75
50
25
0

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0

Speed (kts)

# F/V Savage
# Ship Efficiency vs. Engine Efficiency



# F/V Salty (42ft. Gillnetter): Shaft HP vs. Speed


Shaft Power (HP)

140
120
100
80
60
40
20
0

0
2
4
6
8
10

Speed (kts)

# F/V El Roi (40 ft. Gillnetter: Shaft Power vs. Speed)

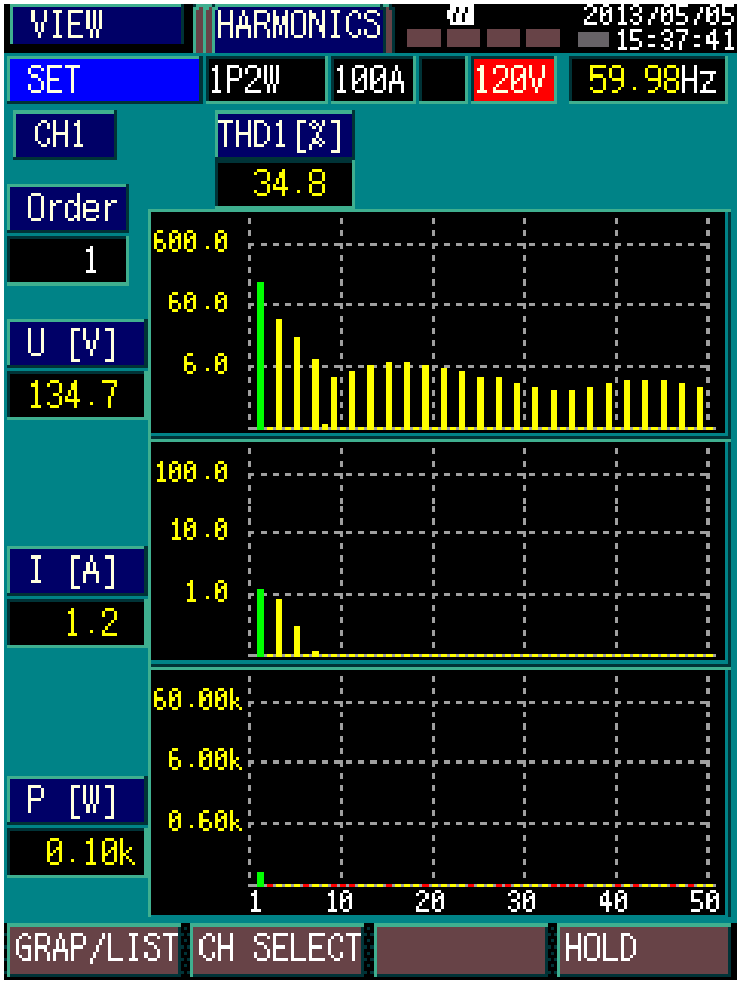

Shaft Power (HP)

140
120
100
80
60
40
20
0

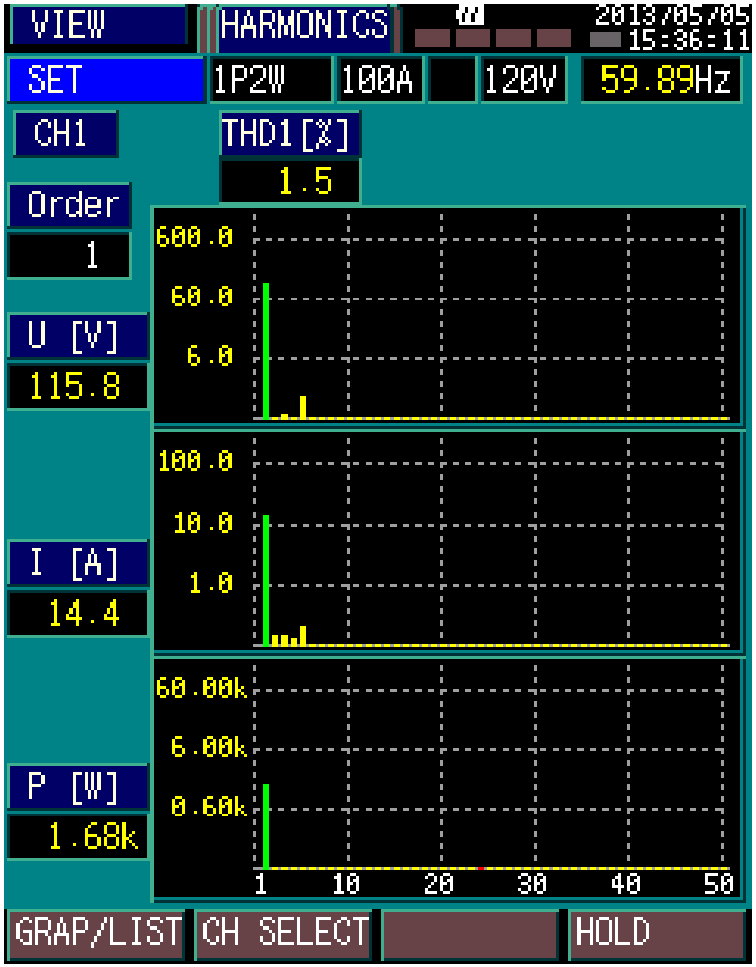
2 3 4 5 6 7 8 9 10

Knots

A/C Power from Inverters
Harmonic Distortion

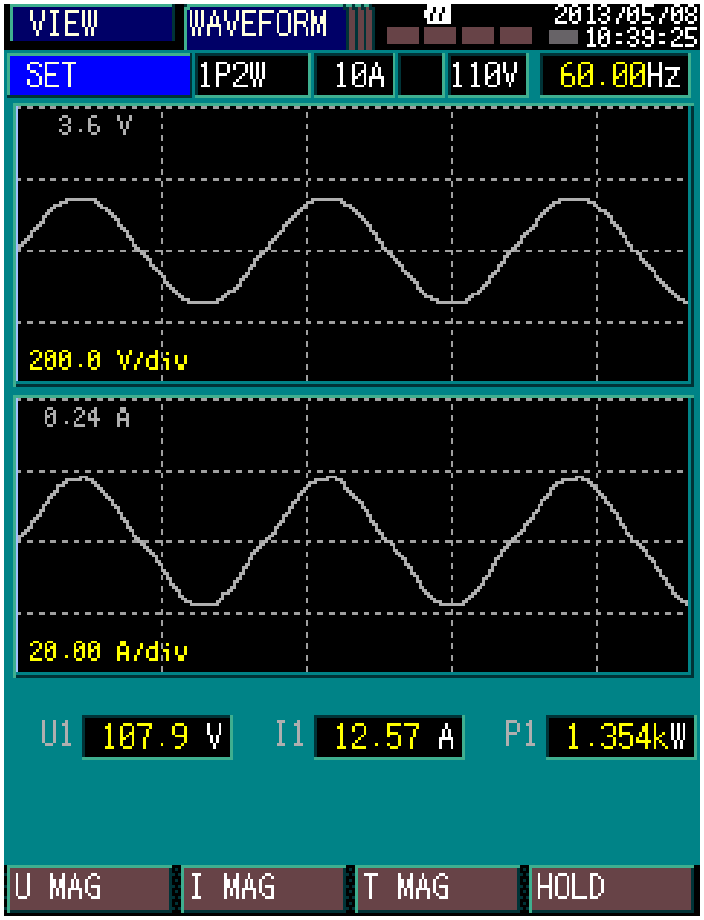



Square Wave Inverter

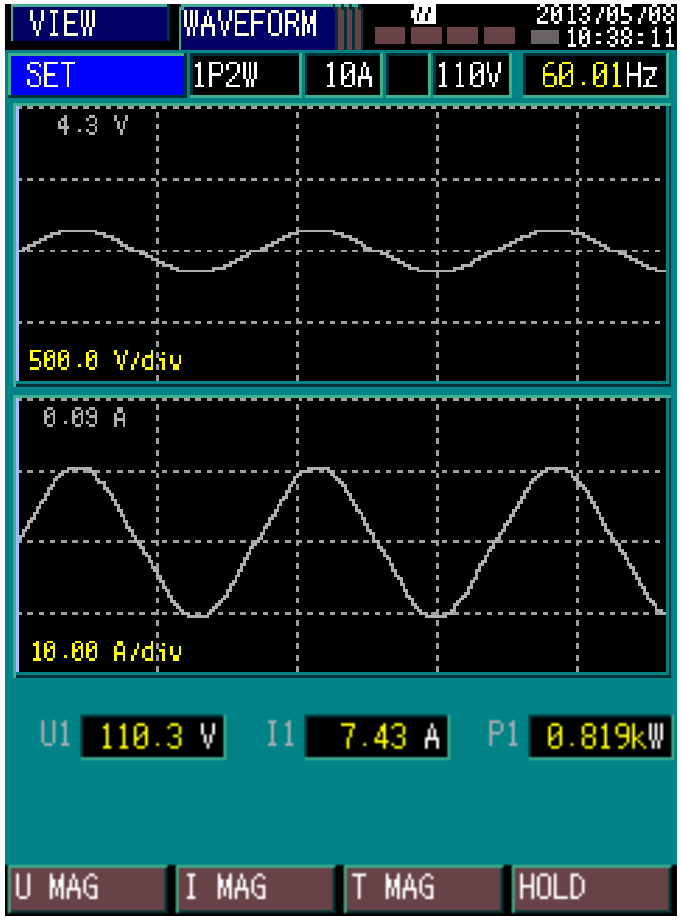



Shore Power

# A/C Power from Inverters
# True Sine Wave Inverters




Sine Wave Inverter




Shore Power

# HIGH EFFICIENCY LIGHTING

| | |
|---|---|
| Initial Cost | $63,519 |
| First Year Savings | $36,866 |
| Payback Period (yrs) | 1.7 |
| ROI | 62% |
| Net Present Value (10 yr) | $340,549 |
| $CO_2$ Savings (MT) | 117.4 |
| Energy Savings (kWh) | 213,962 |
| Fuel Savings (Gal) | 8,999 |

- Fluorescent Bulbs and Ballast
  - T12 Bulbs and Ballast phased out
  - Match  Ballast to Bulbs
  - Specs for Bulbs and Ballast
- LED
  - New Technology
  - Life and Lumen output improved
  - Cost decreasing
  - Ensure quality LED used
  - Thermal Management of LED

# *ENERGY STAR LABEL*

## ENERGY STAR LABEL REQUIREMENTS

- Must be a good investment
- Non –proprietary
- Must deliver same features and performance
- Energy savings and performance tested and verified