GAINING EFFICIENCY IN CONTAINER HANDLING OPERATION WITH REGENERATIVE POWER CHARGING SYSTEM

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Background

- Climate change issue
- Container terminal operator need to come up with ideas
- Some handling equipment are used more frequently than the other

Crucial question :

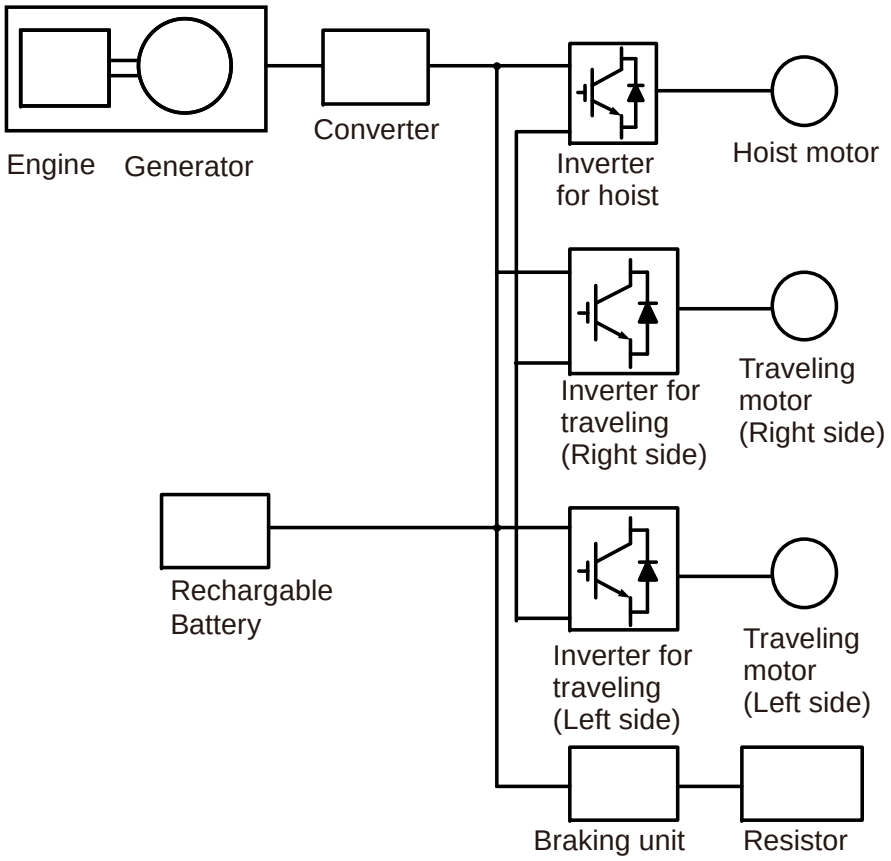
How is environment-friendly technology has been applied?

Which part of operation need attention?

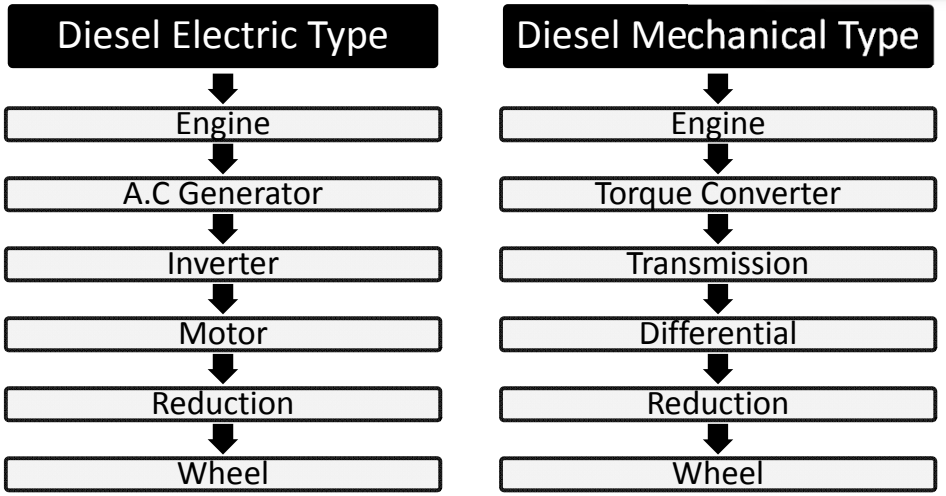
How to measure the implementation?

Application : Hybrid Straddle Carrier

- Straddle Carrier is the most commonly used for In-Yard operation in medium and large sized container terminal
- Widely used in several major port in USA, Korea, Germany and Japan as a complement to conventional diesel-mechanic S.C



Diesel-electric S/C system diagram



Type	: Diesel Electric with inverter
Acceleration Capability	: 30 seconds to reach 20 km/h
Traveling capability	: 23 km/h (with load), 27 km/h (without load)
Hoist/Lowering speed	: 280 mm/sec (with load) 400 mm/sec (without load)
Other characteristic	: Equipped with battery to store regenerative energy by motion

PART I : METHODOLOGY

1. **Designing S/C movement pattern**
2. **Installation of electric data logger in S/C**
3. **Conversion of electric data into real value**

Designing The Experiments (Movement pattern)

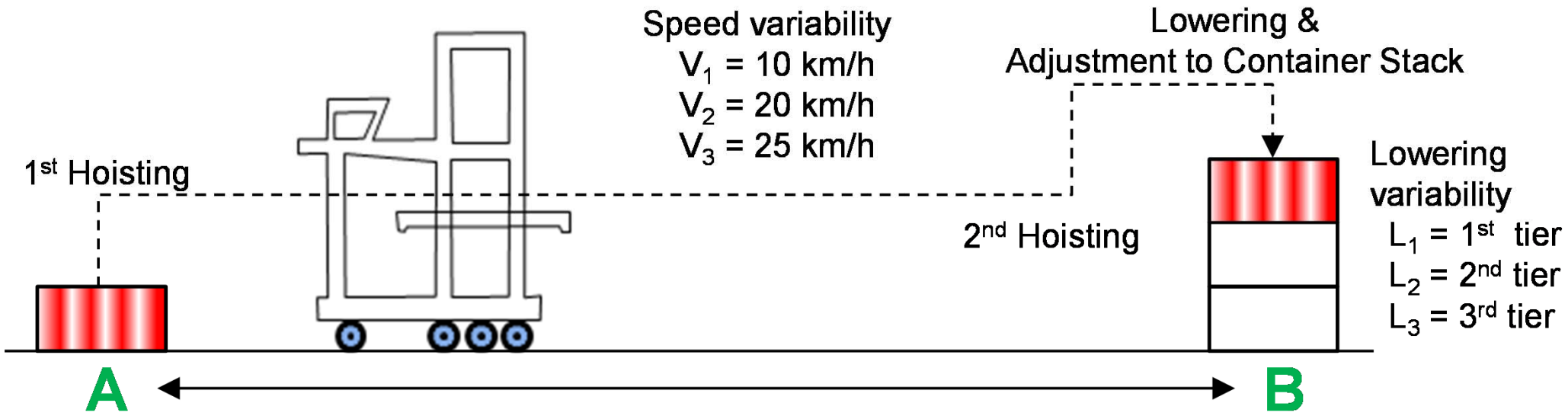
- How to measure the impacts of Hybrid S/C operation in energy saving
- Movement pattern were designed for experimental purposes

Motions of S/C categories (with load and without load)

Handling state

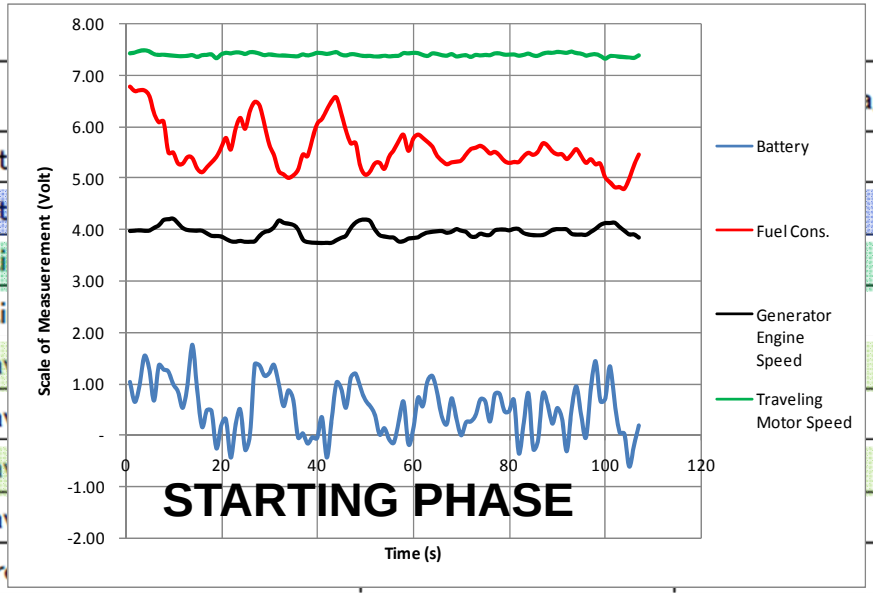
- ❑ Hoisting phase
- ❑ Starting phase
- ❑ Cruising phase
- ❑ Braking phase
- ❑ Lowering phase

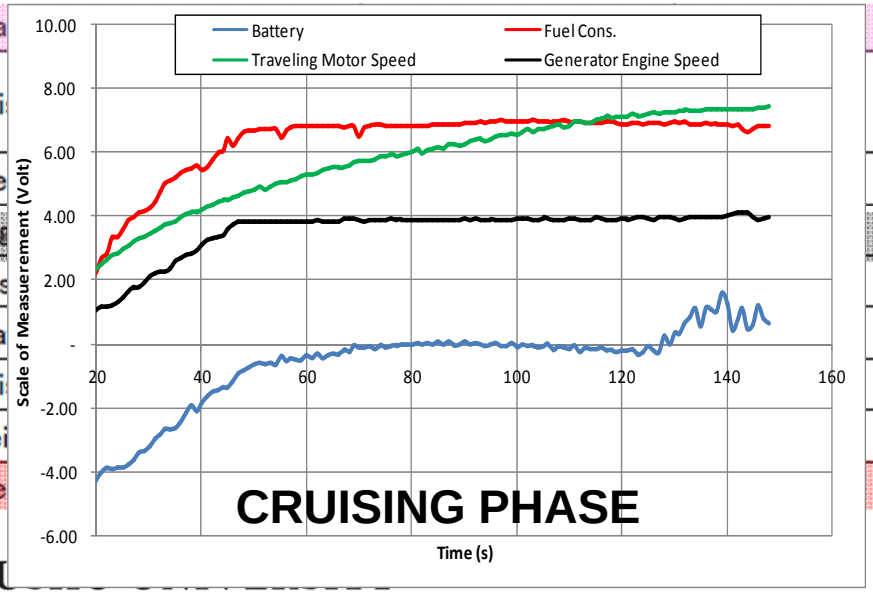
Traveling state



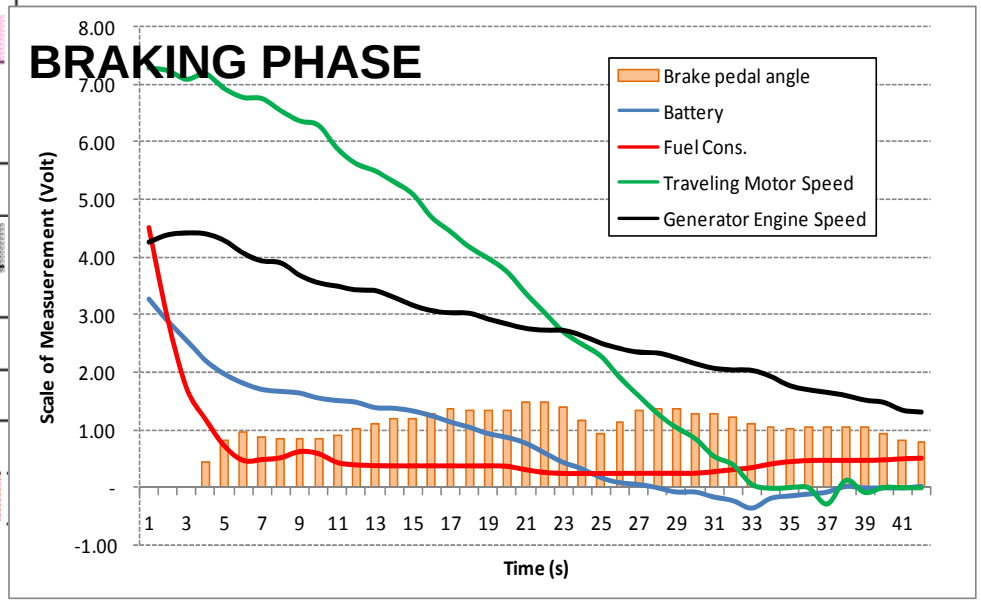
Designing The Experiments (Data logger)

- Measuring the electrical output → easily separate the output from various range of machinery equipment



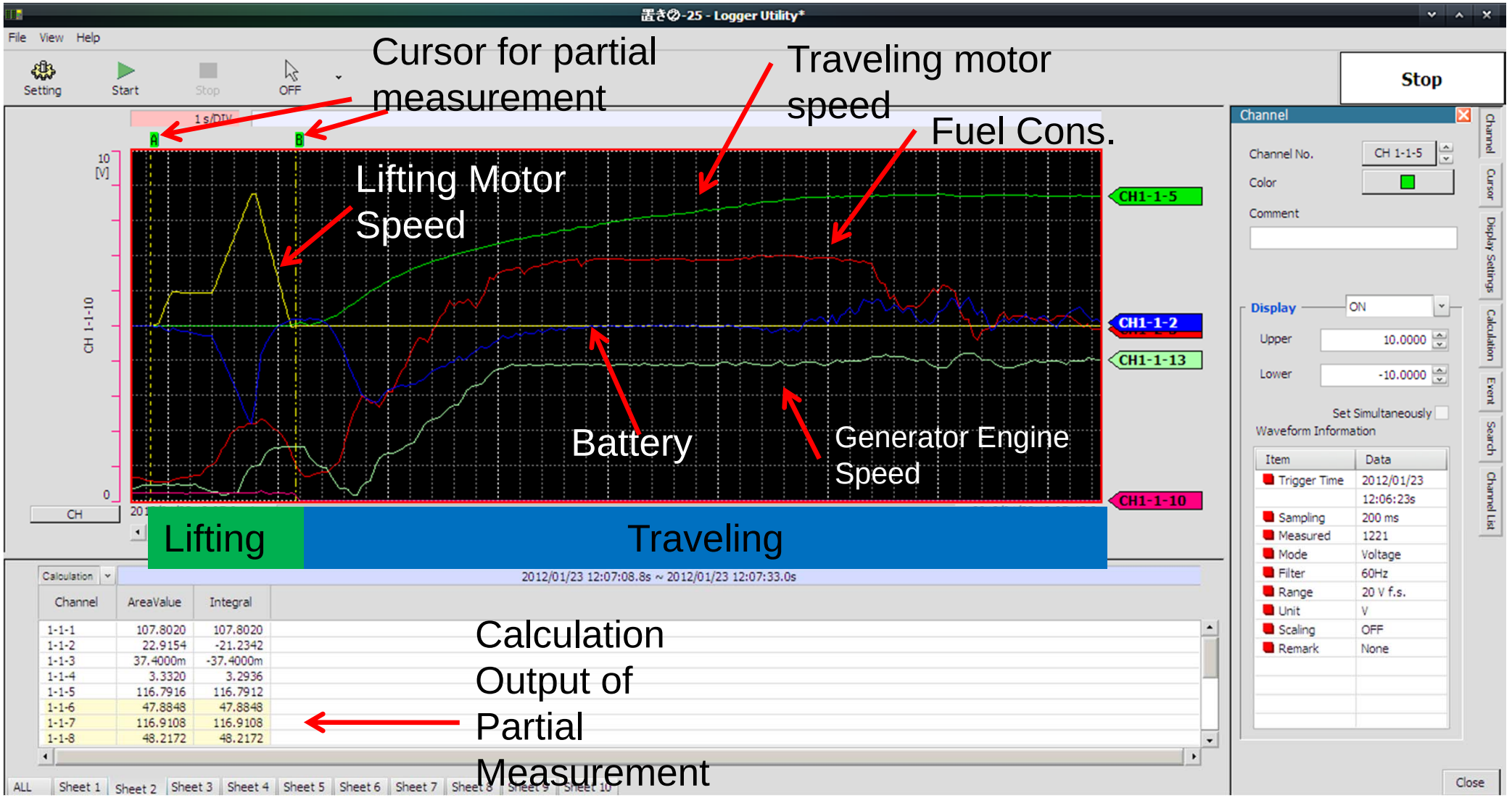


- Voltage data logger is installed in the S/C
- Output performances from continuous and temporal activity is are recorded in data logger (HIOKI LR8400-20)
- Recorded data in voltage is exported to CSV data
- SCV data is converted into real value and analysed



Example of Waveform Analysis

Note : Recorded Time interval = 0.2 seconds, Output = voltage resolution of 0.5 mV in the 10 V



Data Conversion to Real Value

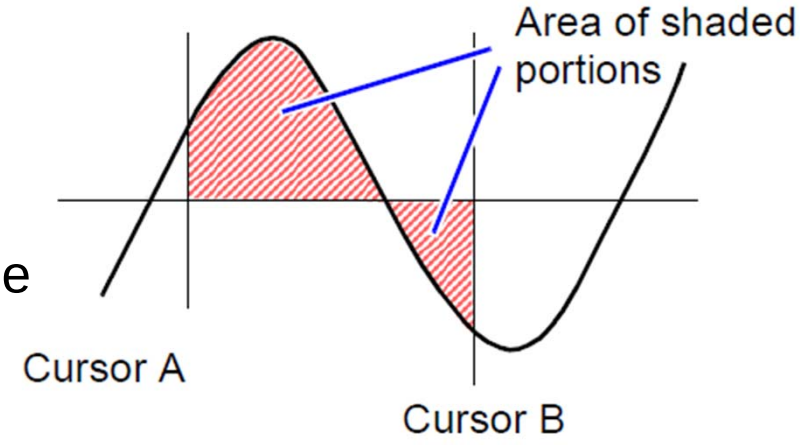
- Converted the waveform to show the relation in real value and divided the analysis into lifting & traveling process
- Measured the value for each channel output by ACV (average channel value)

$$ACV = \left(\left(\sum_{i}^{n} di \times \Delta t \right) \div n \right) \times \left(\frac{M}{O} \right)$$

Converting value

Averaging value

Integration of shaded portions



Remarks:

n = total number of data items

d*i* = data on channel number *i*

Δt = sampling period

M = Max measurement range

O = Max output voltage

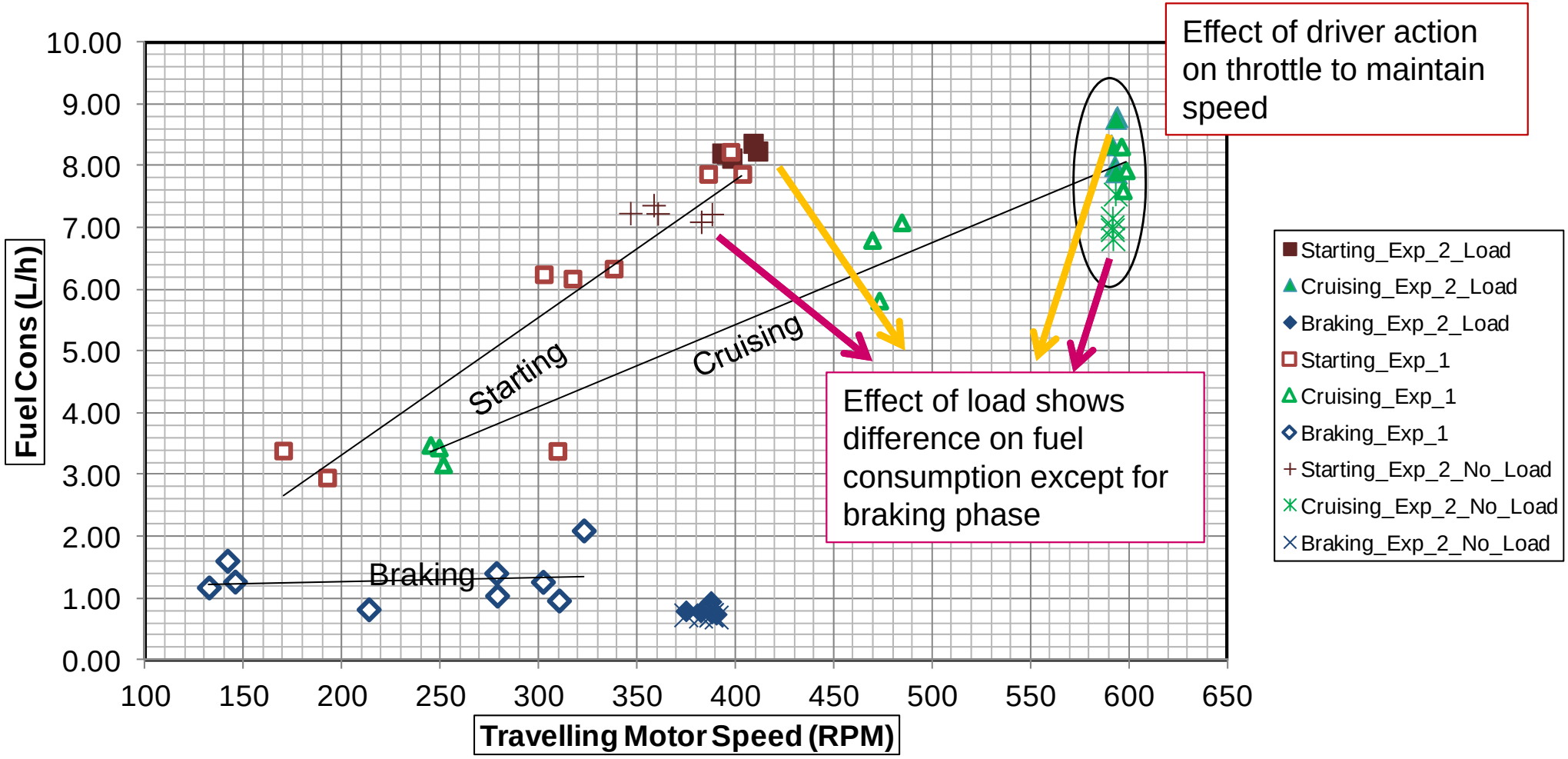
ACV = Average Channel Value

PART II : MOVEMENT ANALYSIS

1. **Traveling Analysis**
2. **Hoisting/Lowering Analysis**

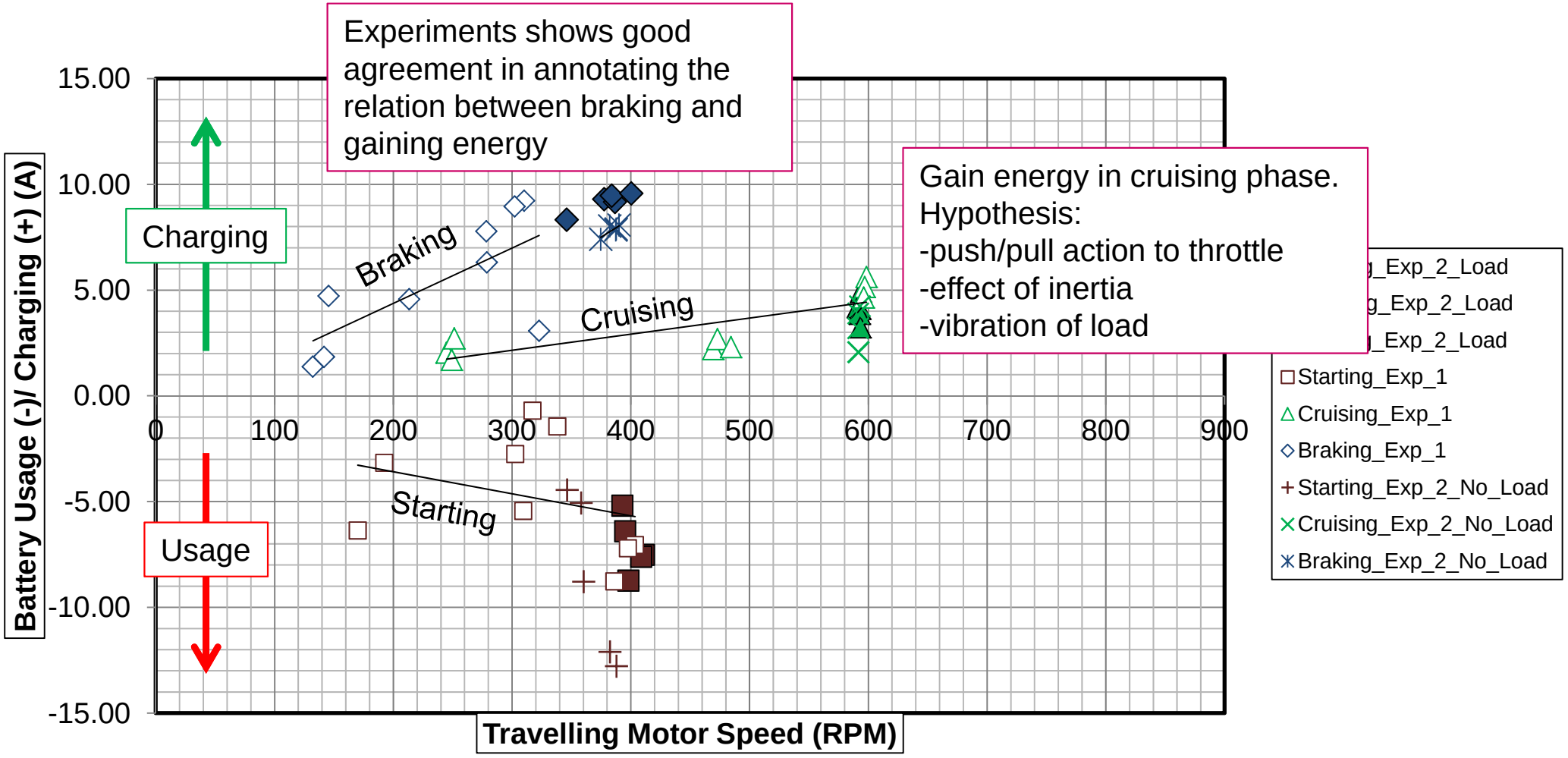
Traveling Analysis – Fuel Consumption

- 3 kinds of traveling experiments were conducted
  - Exp_1 is for changing in travel speed
  - Exp_2 is for changing in acceleration but maintain traveling motor speed with a container load
  - Exp_3 is similar with Exp_2 only without a container load to S/C.



Traveling Analysis – Regenerative Energy

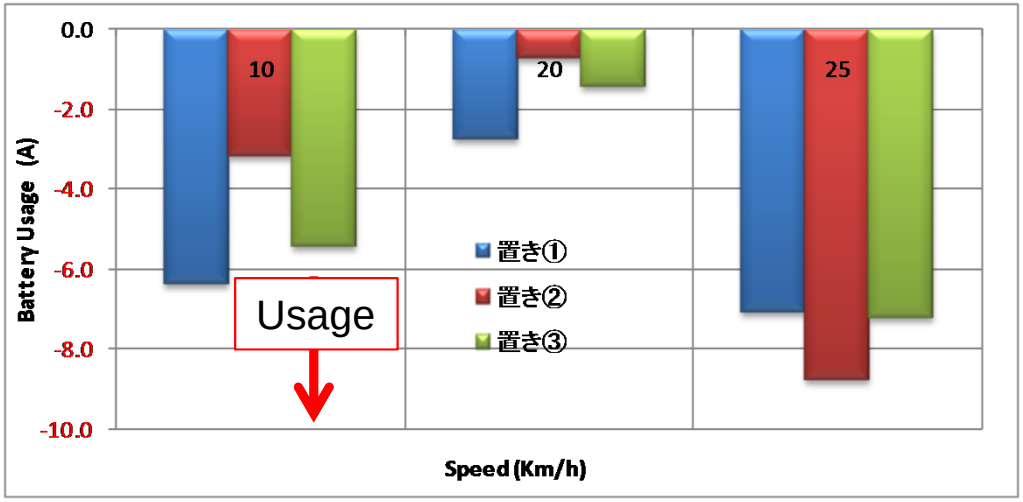
- **Regenerative energy** : energy recovery mechanism which slows a vehicle or object down by converting its kinetic energy into electric power and the stored saved in a storage battery and used later to power the motor for another use, such as hoisting, powering air conditioner in the control room and lights.



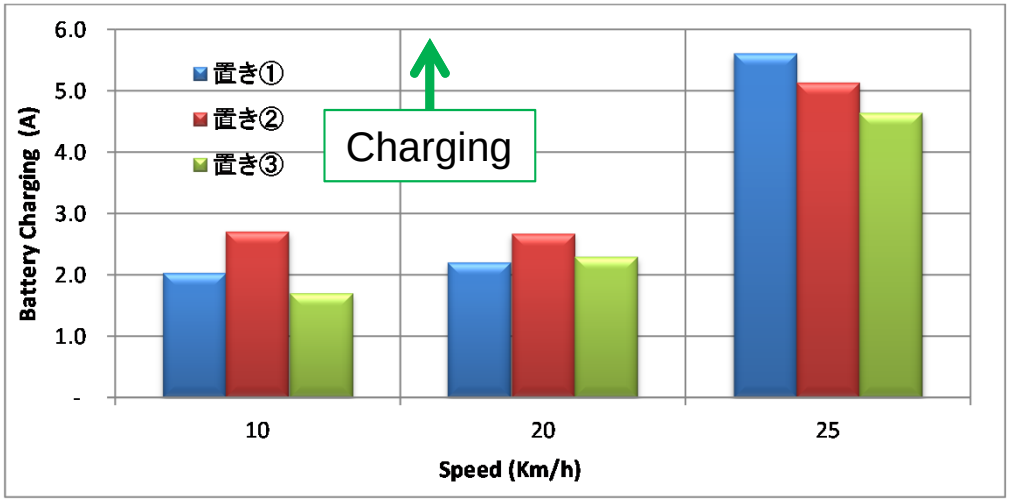
Impact of Traveling Speed (Pre-Analysis)

Higher Traveling Speed produce more battery charging, mainly during braking

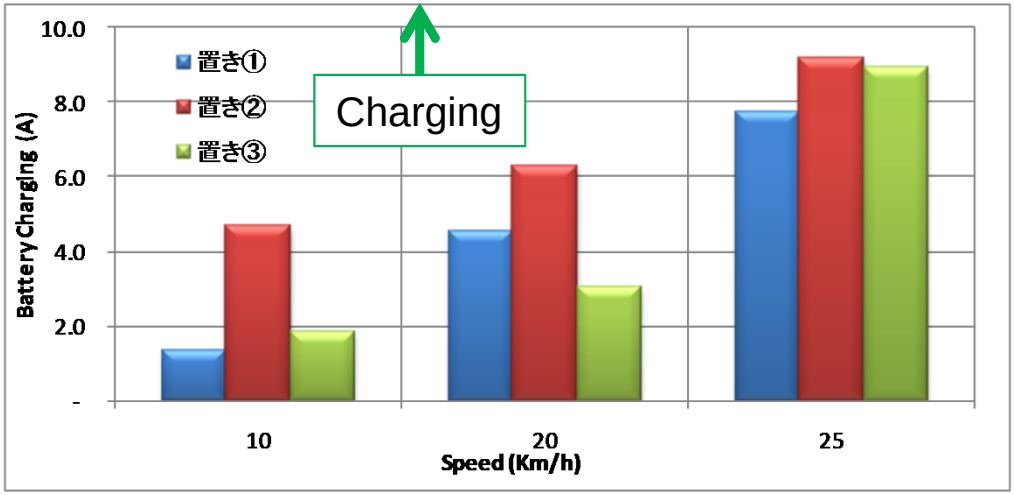
STARTING PHASE



CRUISING PHASE



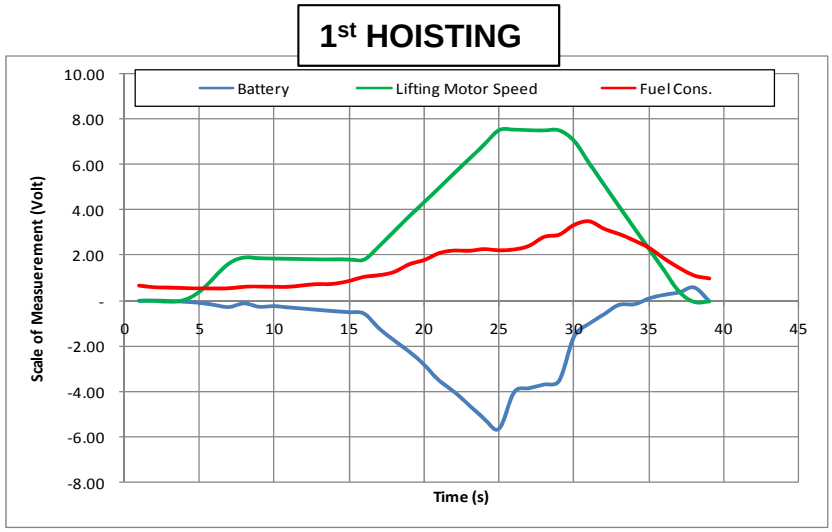
BRAKING PHASE

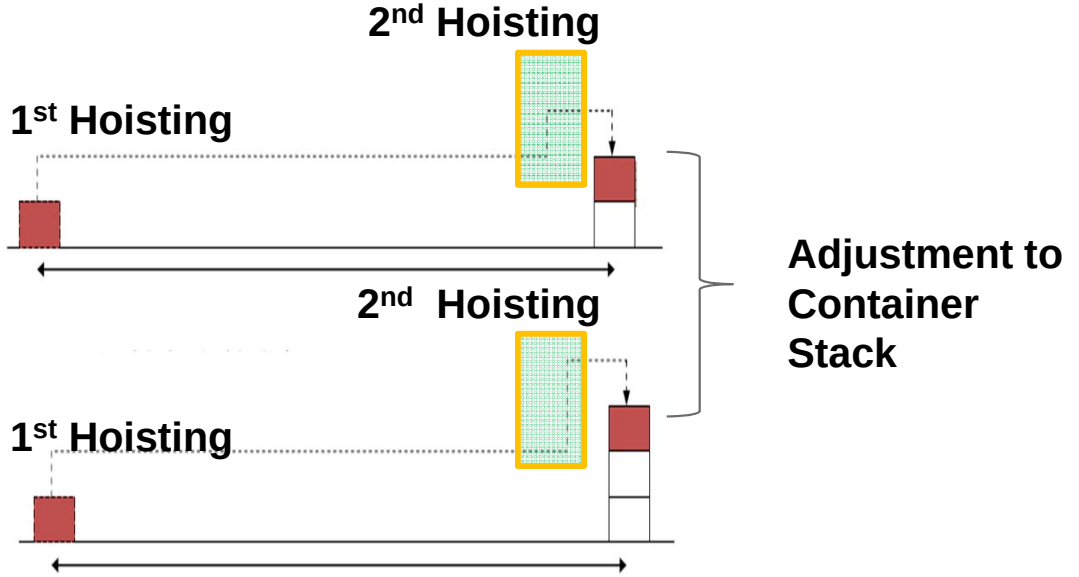


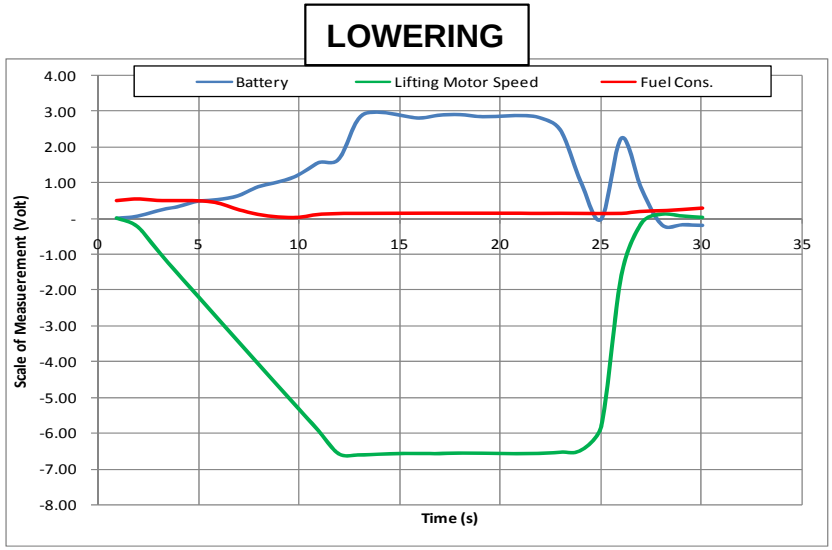
Pattern	Speed (km/h)	Battery Usage (-)/ Charge (+) (A)			
		Starting	Cruising	Braking	**Total**
置き①	10	-6.4	2.0	1.4	-3.0
	20	-2.7	2.2	4.6	4.0
	25	-7.0	5.6	7.8	6.3
置き②	10	-3.2	2.7	4.7	4.3
	20	-0.7	2.7	6.3	8.3
	25	-8.8	5.1	9.2	5.6
置き③	10	-5.4	1.7	1.8	-1.9
	20	-1.4	2.3	3.1	3.9
	25	-7.2	4.6	9.0	6.4

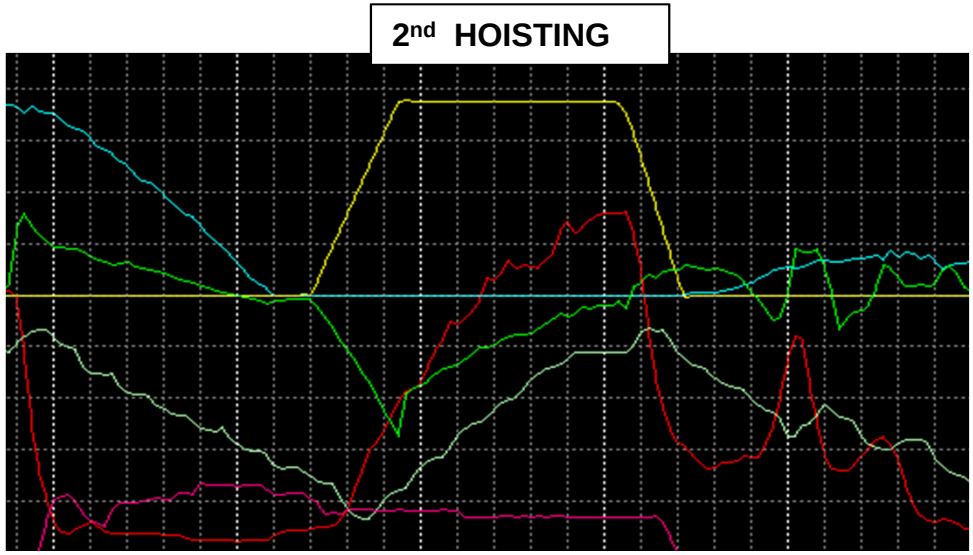
Hoisting/Lowering Analysis

- Measuring correlation between lifting speed and fuel consumption as well as to battery usage/charging with variability in hoisting speed and stacking position



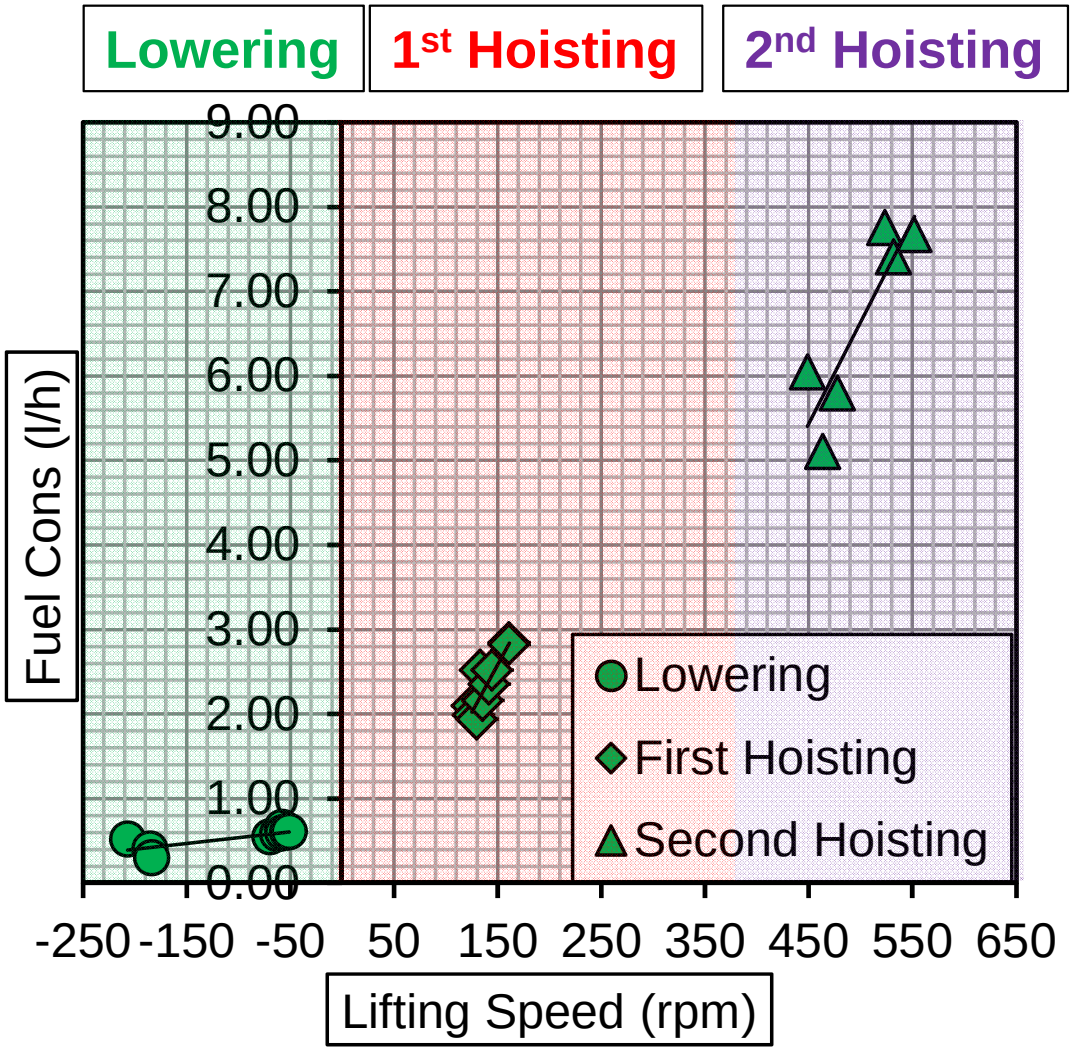


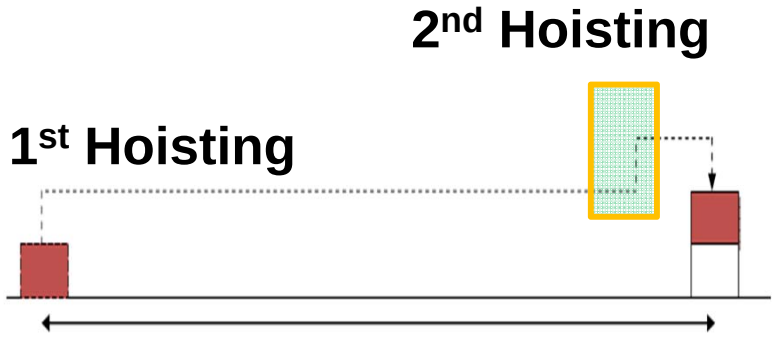




Hoisting/Lowering Analysis – Fuel Consumption

- Lowering and Hoisting operation shows good agreement with normal performance parameter and assumption





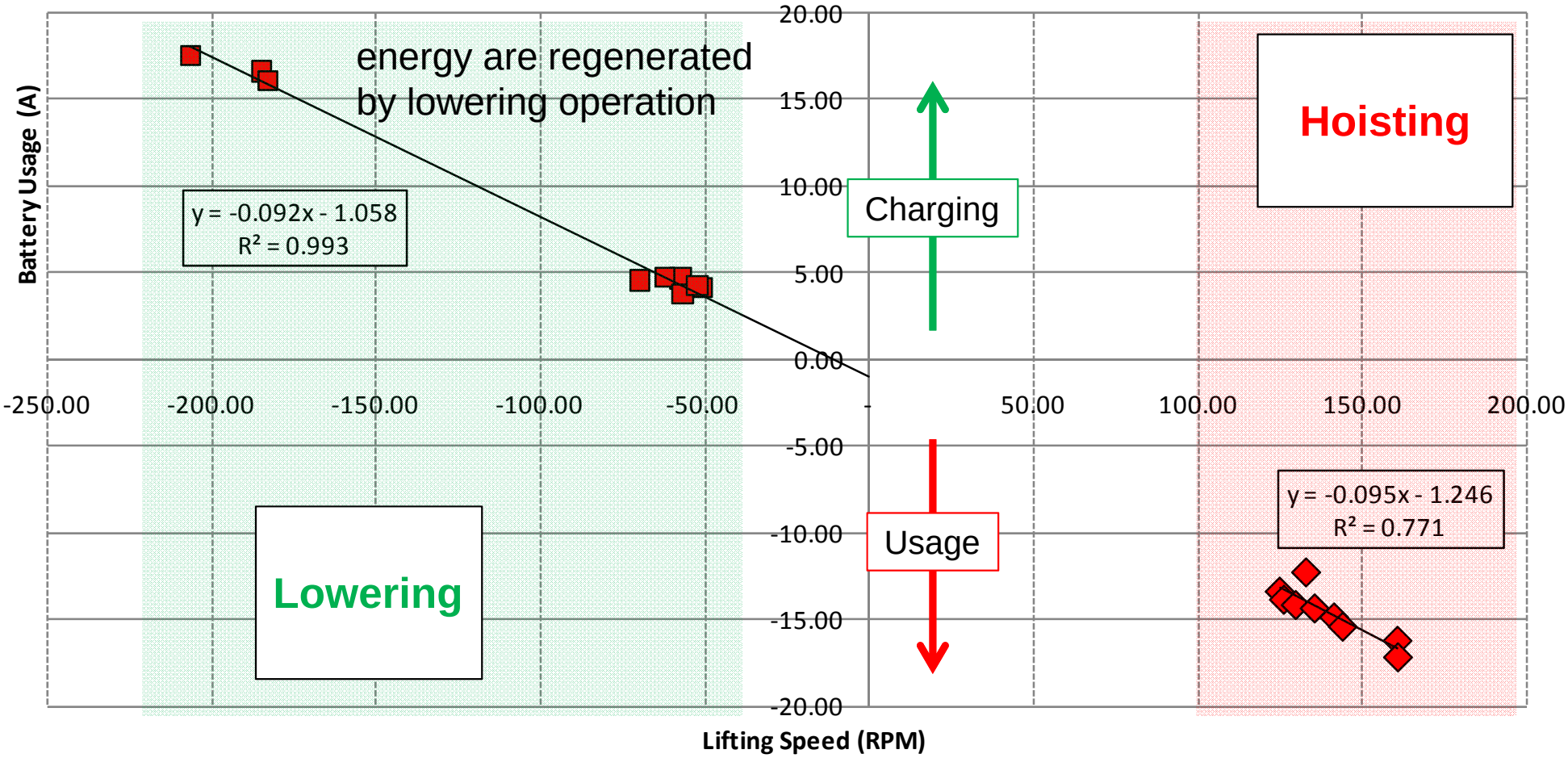
Intriguing phenomena : Increase in fuel cons during 2nd Hoisting

Hypothesis : Data might be distorted as 2nd Hoisting is conducted while traveling

Hoisting/Lowering Analysis – Regenerative Energy

Strong correlation between lifting speed and alternate performance parameter of battery utilization

Future issue : Can regenerative energy (lowering) be used to compensate energy usage during hoisting?



Conclusion

- This preliminary study proposes methodology to assess and measure the efficiency of hybrid straddle carrier (Hybrid S/C) in the form of fuel consumption and gained regenerative energy by motions.
  - Combination of data logging instrument, logger utility software and spreadsheet is used to capture electronic output
  - Electric data is successfully converted using the proposed ACV calculation

- Analyzed data show good agreements in relation between traveling speed / lifting speed with either fuel consumption and battery charging
  - Regenerative energy can be gained through the following operation
    - Traveling - Braking phase → with more traveling speed
    - Lowering operation

- Future research will focus on :
  - Assessing appropriate driving method and movement cycle (GPS and Video Camera)
  - Comparing operational performance of Hybrid S/C and Conventional S/C