Ship Efficiency Conference
Hamburg | Sept 23-24, 2013

PROPULSION DYNAMICS

PRELIMINARY

Developing a more fuel efficient tonnage through blasting of hulls and timely in-water husbandry. (and shared benefits between owner and charterer)

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Agenda

1. Introduction to hull and propeller performance monitoring
2. Timely in-water husbandry
3. Blasting of hulls in dock
4. Shared benefits for owner / charterer

1. Introduction to CASPER®

- Hull and propeller performance monitoring (and relation to actual FOC) was accomplished utilizing CASPER (**C**omputer **A**ssisted **S**hip **PER**formance).

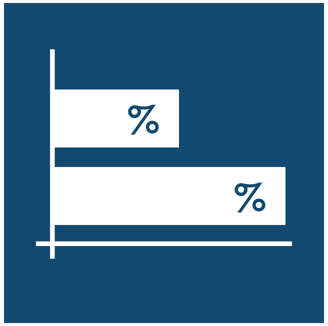
The Technical Concept

a+b=c

Establish a mathematical performance model for each vessel, covering all speeds, drafts and weather factors, based on the sea trial data.

Vessel submits a weekly performance ‘observation’ dataset (steady state).

Increase in resistance (Added Resistance) of hull and propeller due to roughness and fouling is calculated to measure performance.



Then compares the actual performance to the performance under sea trial (clean, smooth hull and propeller) condition.

Added Resistance is reported in percentage (in percent of the total resistance, design draft and speed). Allows for non-dimensional fleet-wide comparisons.

Differentiating from other systems

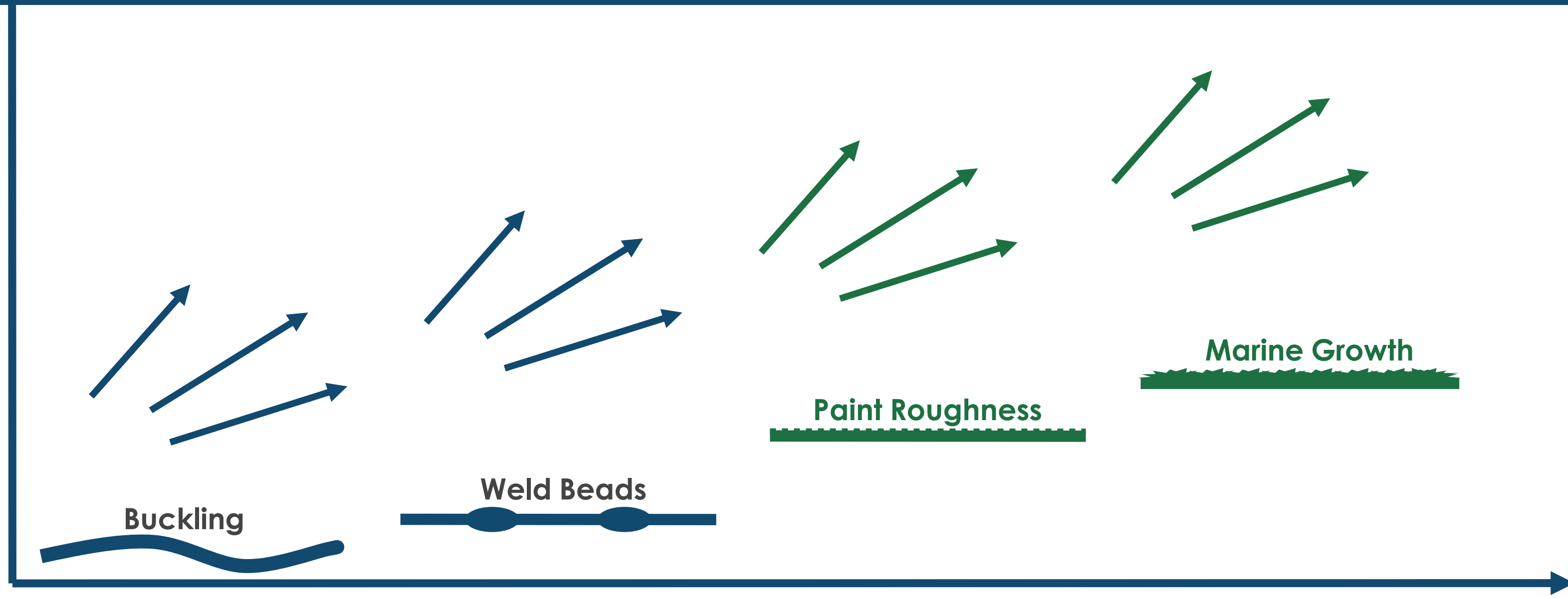
- Added Resistance is an index to measure performance rather than Speed Loss for the following reasons.
  - Speed loss is represented with reference to design speed but few vessels operate at design speed these days.
  - Speed loss does not provide a perspective of the magnitude of roughness or fouling as clearly as Added Resistance. (Speed loss is the 3rd root of the added resistance).
  - Speed log error can be significant and causes uncertainty in speed calculation.
- Speed was not an input into the Added Resistance calculation, rather Speed is calculated from rpm, prop characteristics and power. Reported Speed (log) is only a parameter to validate the calc. Speed.

The added hull resistance is defined as the additional hull friction force caused by the fouling as a % of the total clean ship resistance at the design draft and the design speed.

The "added resistance" for the propeller simply means the loss of propeller thrust as a percentage of the propeller thrust for the clean ship at design draft and design condition.

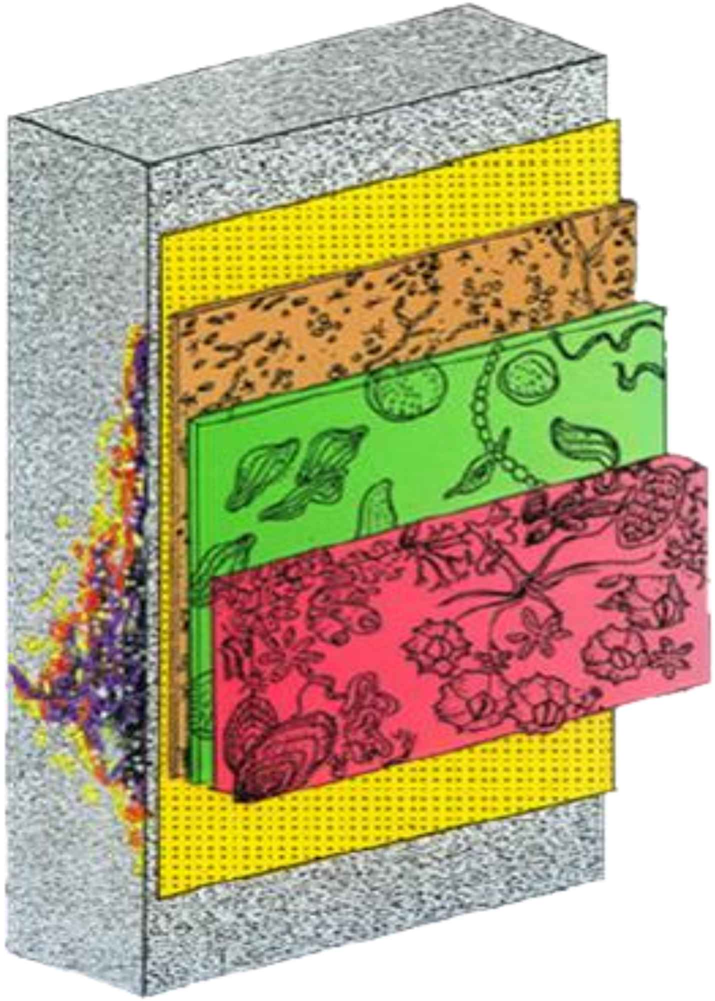
2. Timely In-water Husbandry

Surface Hull Roughness



Courtesy: Norwegian Technical University

Stages of Marine Growth



Surface Penetration

Molecular Fouling
conditioning film

Microfouling
bacteria
microalgae
fungi

Macrofouling
macroalgae
invertebrates

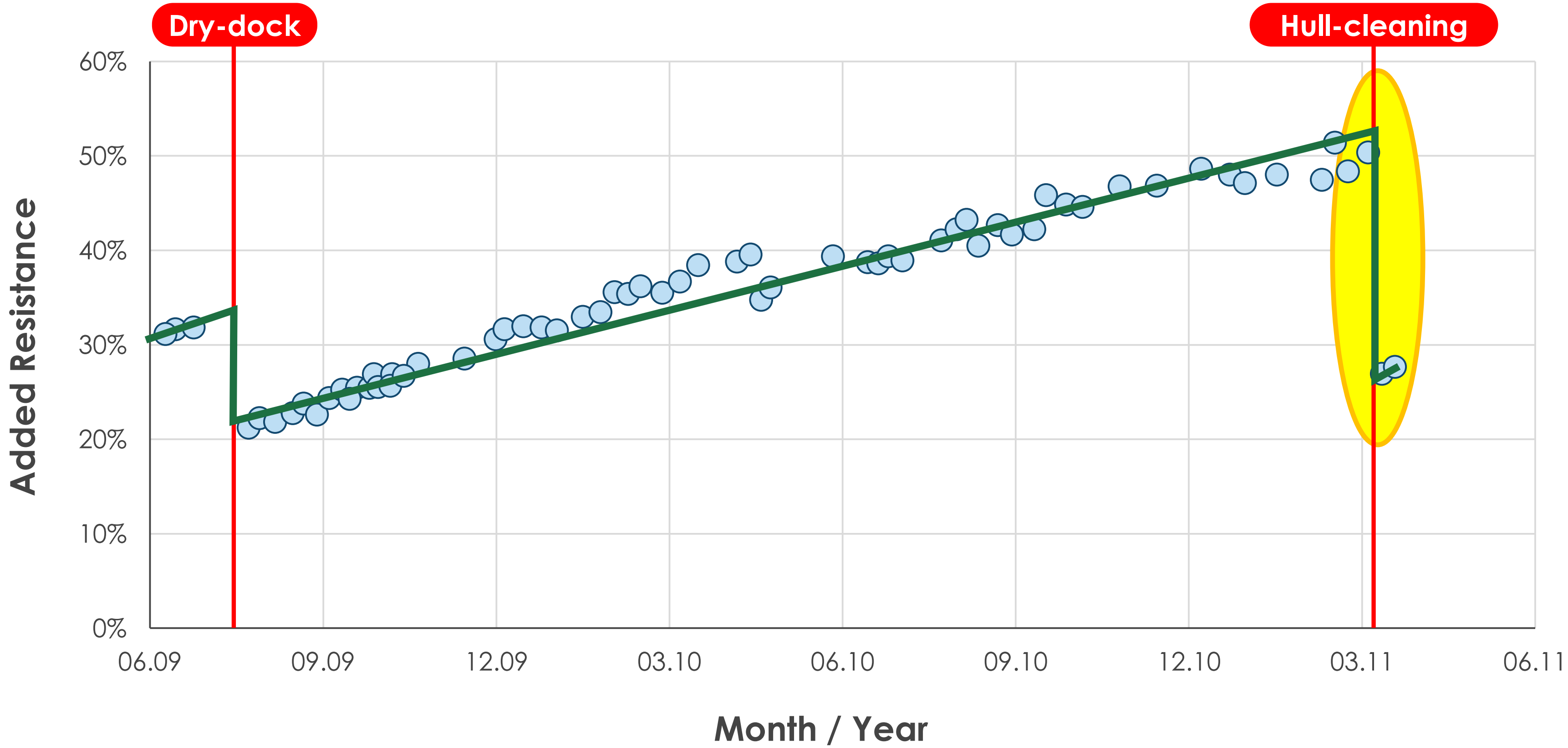
Natural anti-fouling

Status of World Fleet (average)

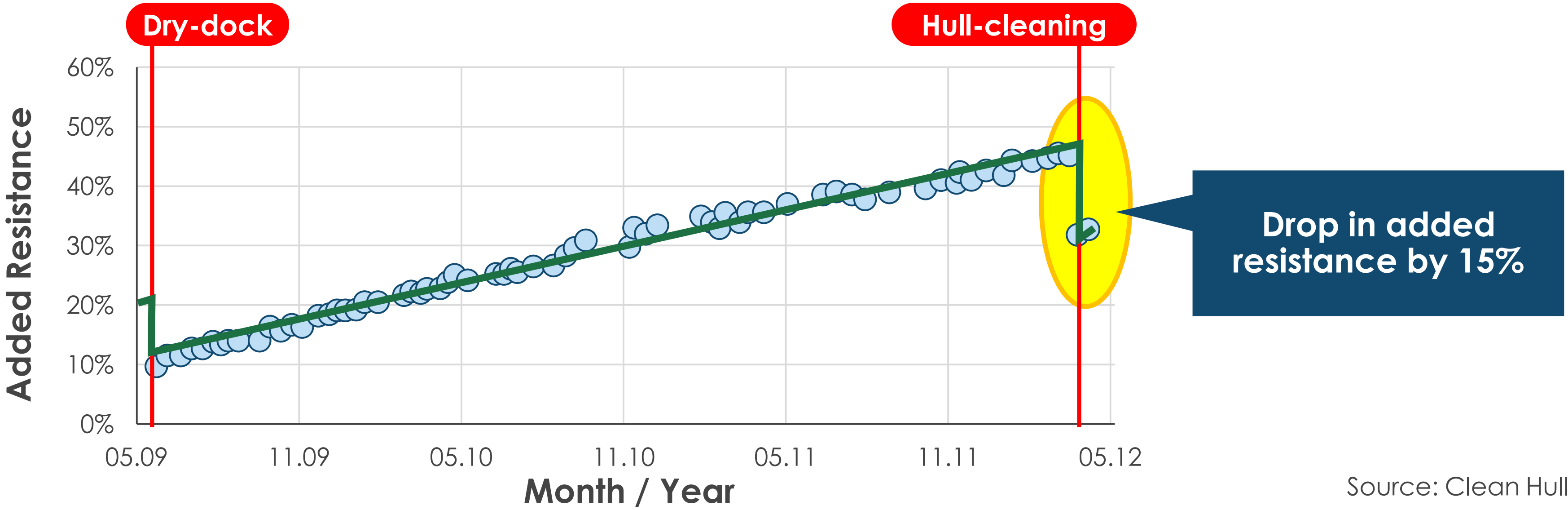
Ship type	Avg. Added Resistance % (reference trials)	Excess FOC (design speed, draft)	Speed Loss (design speed, design draft)	**Fuel savings for hull** prop cleaning **if done today**	Losses due to basic roughness
Aframax	26.3%	7.2 t/day	0.84 kn	4.2 tons/day	3.0 t/day
Suezmax	29.5%	9.8 t/day	0.94 kn	5.1 tons / day	4.7 t/day
VLCC	27.7%	18.2 t/day	0.92 kn	5.9 tons / day	12.3 t/day
Pana boxship	34.0%	44 t/day	1.7 kn	14 tons / day	30 t/day
Post Panamax	36.1%	53.4 t/day	1.9 kn	22 tons / day	31.4 t/day

Quantifying effect of maintenance

- Effect of hull cleaning is reflected in terms of drop in resistance
- Quantification of this drop in resistance is shown in the next slide



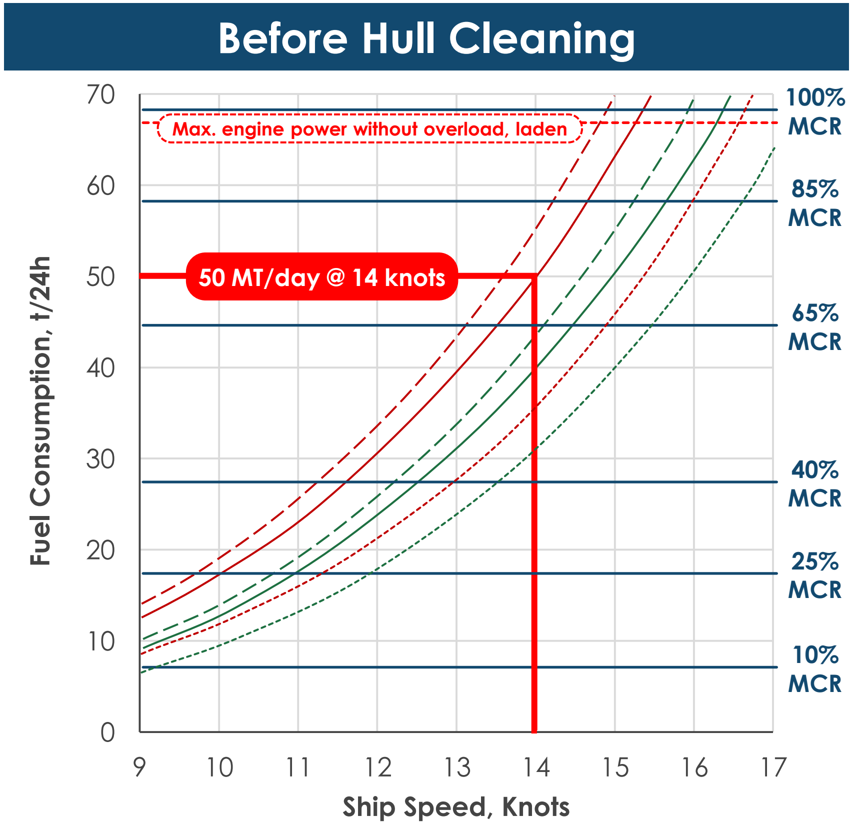
Effect of Hull Cleaning

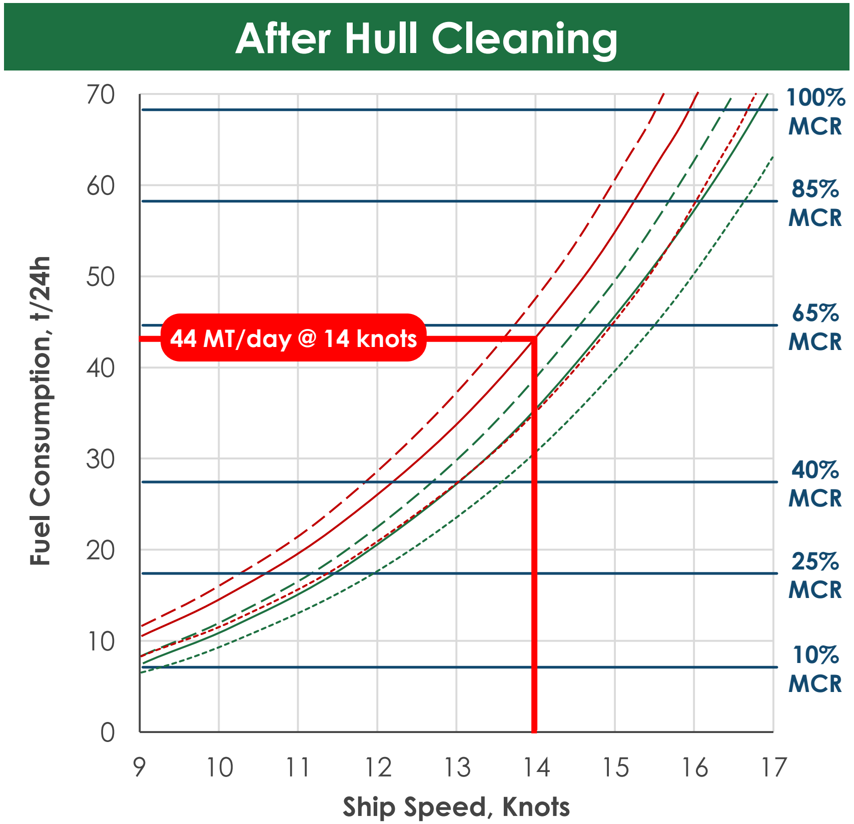


Source: Clean Hull

CASPER – Quantifying effect of maintenance

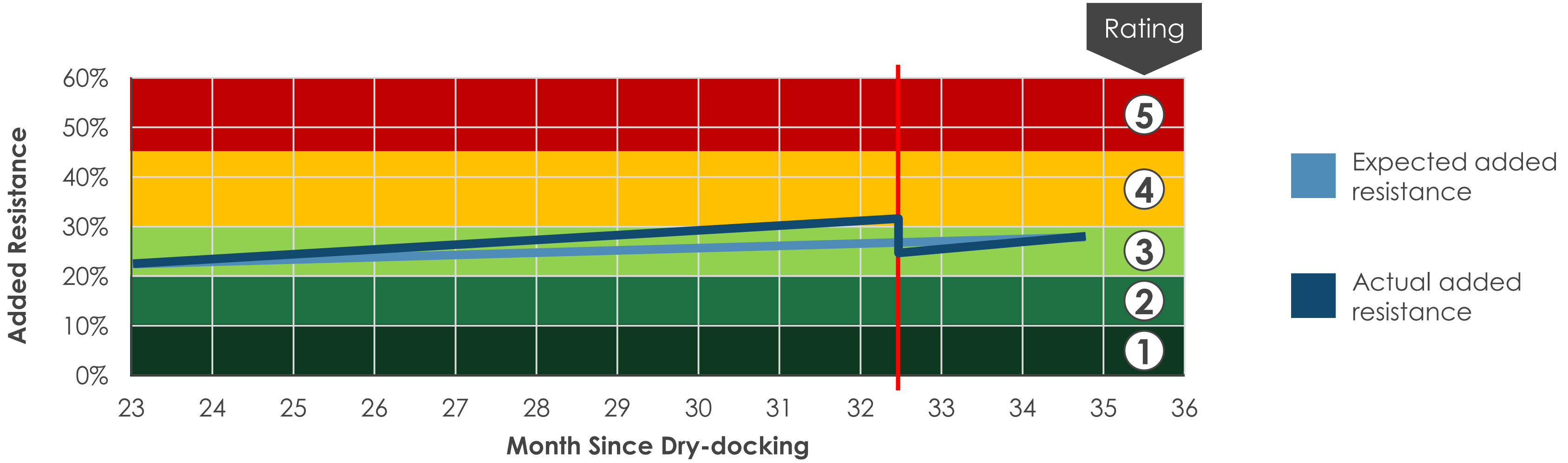
Hull cleaning resulted in a fuel saving of 6 MT/day @ 14 knots speed in laden condition @ Beaufort 0.





Timely maintenance

- Hull & Prop condition starts deteriorating after the vessel is delivered.
  - — ***thresholds for acceptable*** hull & propeller performance (shown below) over the long term asset life.
  - — benchmark performance after drydocking or plan an appropriate schedule for hull / propeller cleaning, compare hull coatings, etc.
- Classify / categorize performance of vessels as shown below to make it understandable for all stakeholders (technical or nontechnical).

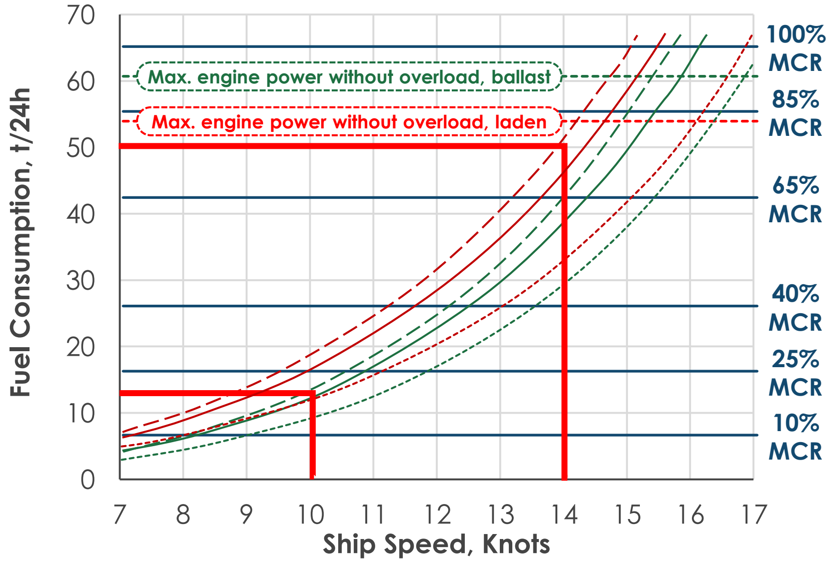


CASPER

Effect of Hull Cleaning

- Comparison of Speeds & Consumptions before & after Hull Cleaning
- Laden Consumption @ 14 knots - 50.5 MT / day vs. 47 MT / day
- Ballast Consumption @ 10 knots - 16 MT / day vs. 15 MT / day

Before Cleaning



After Cleaning

CASPER

Proving the benefit independently for all stakeholders

- Based on 140 Laden days & 160 Ballast days per year

From previous slide:

- Fuel saving in laden passage : 3.5 MT / day
- Fuel saving in ballast passage : 1 MT / day

Total Fuel saved per year:

Fuel savings	= (140 x 3.5) + (160 x 1)
	= 590 MT / year
@ $ 650 / MT of HFO	= 590 MT x $ 650
	= $ 383,500

Reduced CO_2 emissions per year:

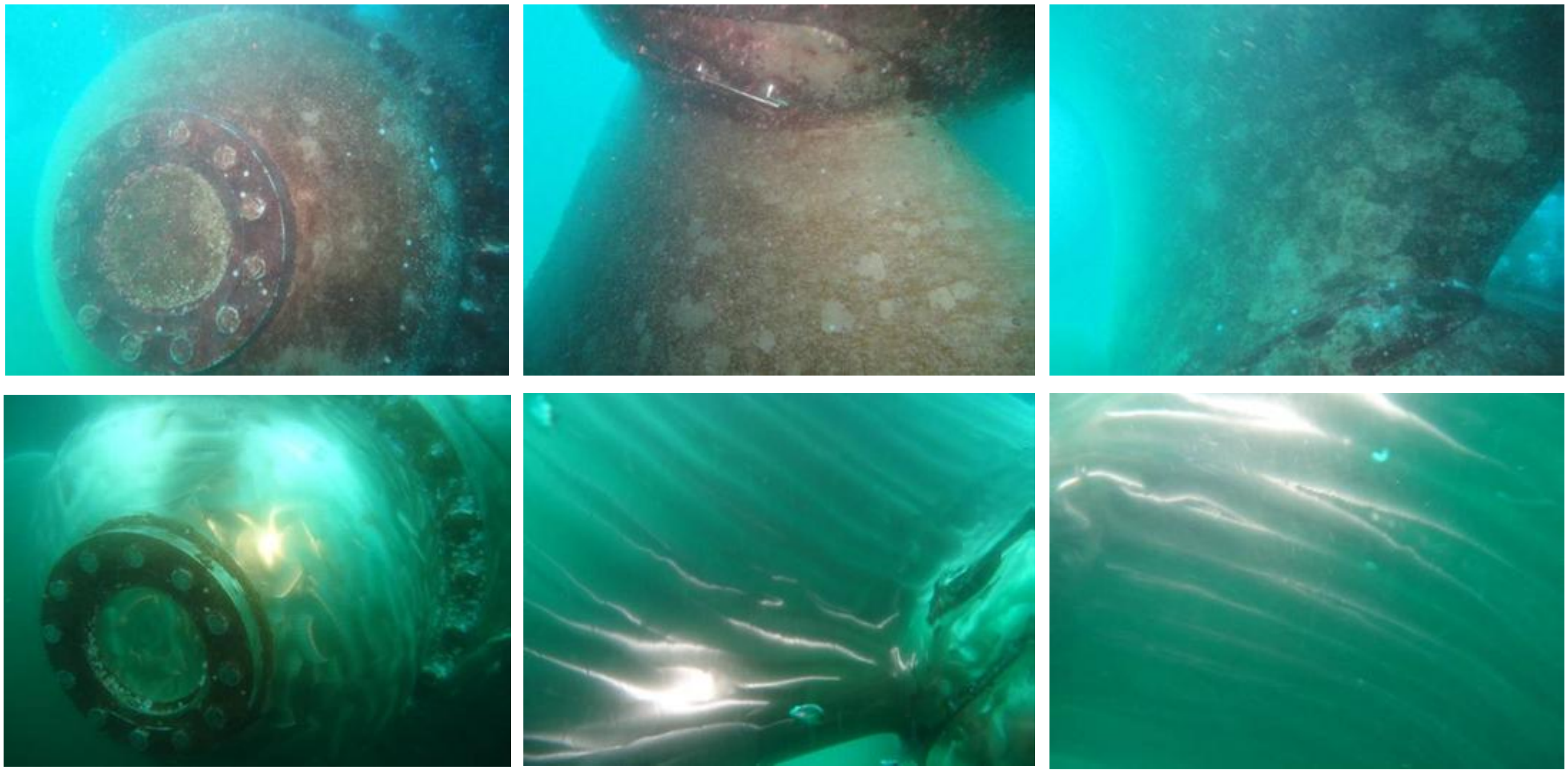
= 590 MT x 3.2 MT of CO_2 per MT of Fuel

= 2,080 MT of CO_2 / year

Since the benefit diminishes after hull cleaning, considering even a 50% benefit from the above is significant.

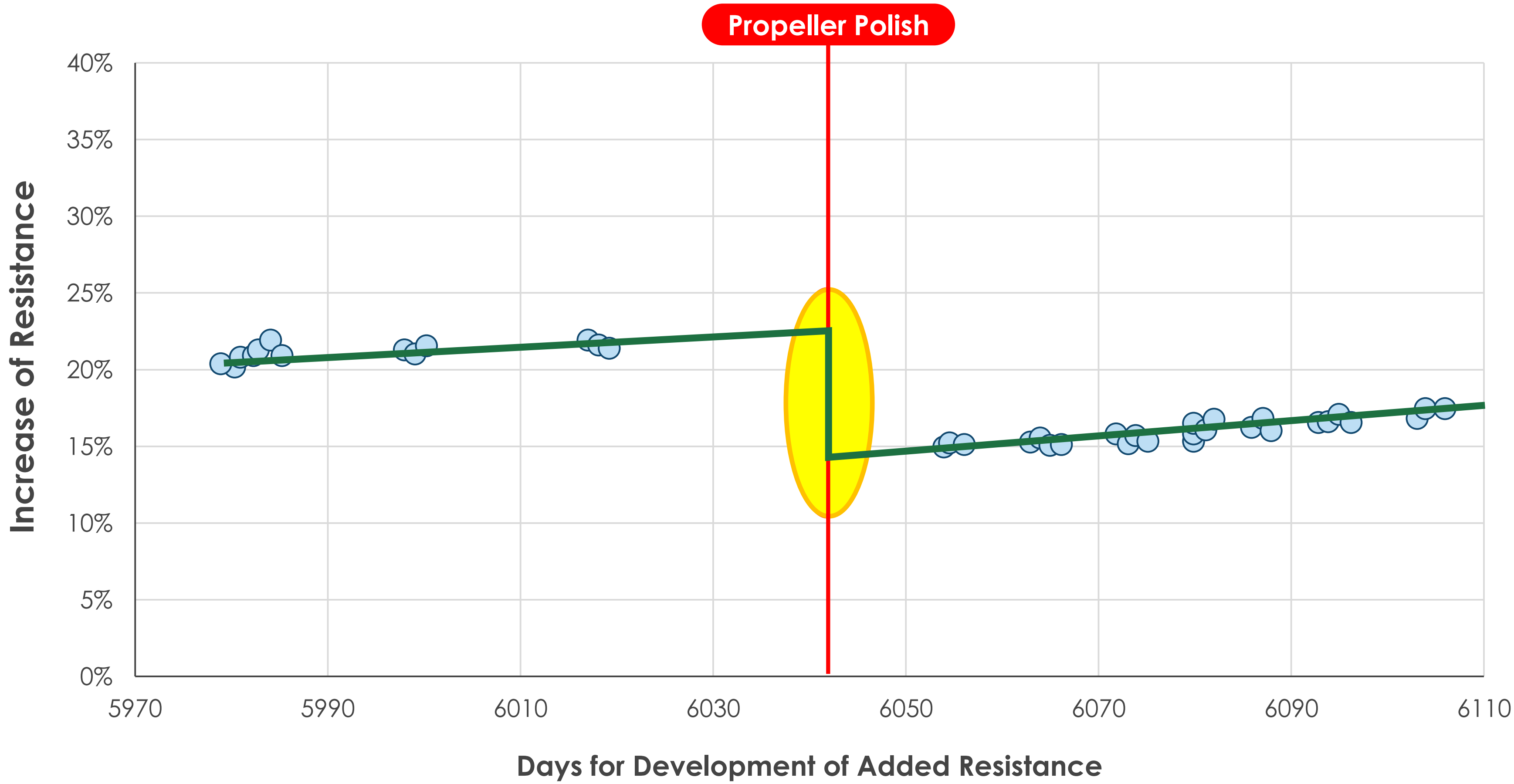
CASPER – Quantifying effect of maintenance

Before & After Propeller Polishing



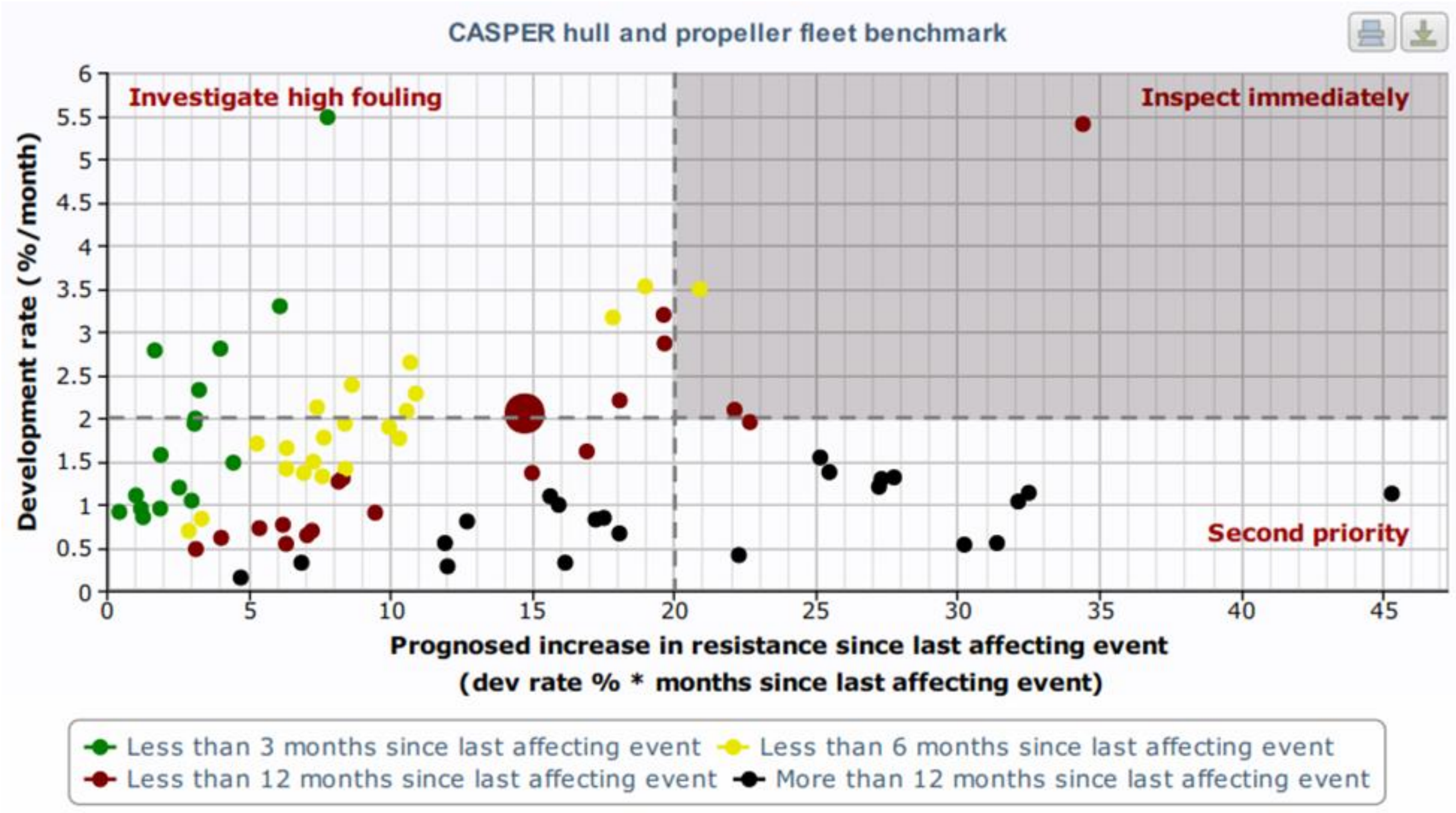
CASPER – Quantifying effect of maintenance

Effect of propeller polish lead to a 7% drop in resistance

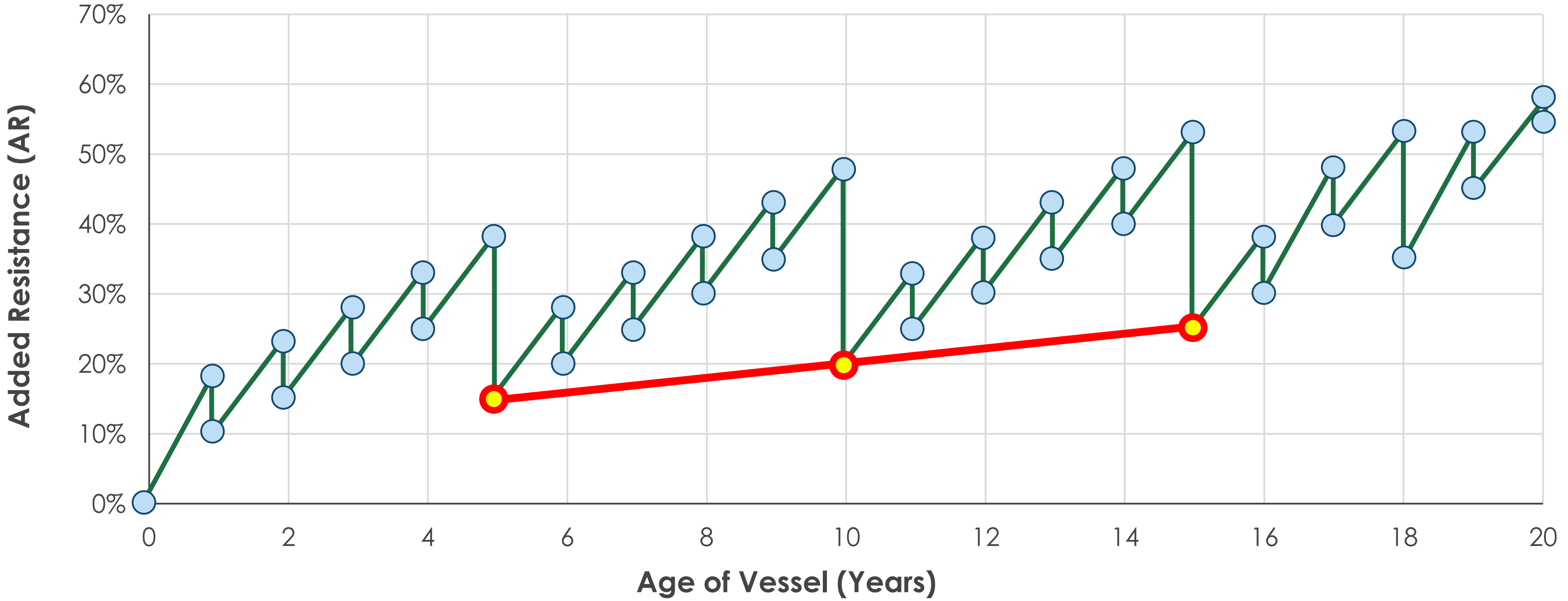


Fleet tool (below is plot of 65 ships)

Y-axis represents how fast hull and prop are fouling
Y-axis represents how much the hull+prop resistance has increased since last husbandry



3. Blasting of hulls



Example shown is a ship with yearly prop polish and 5 yr docking.

5 yr.=0.50 kn. | 10 yr.=0.73 kn. | 15 yr.=0.85 kn. | 20 yr.=1.7 kn.

Speed loss increases over docking intervals (when only spotblasted)

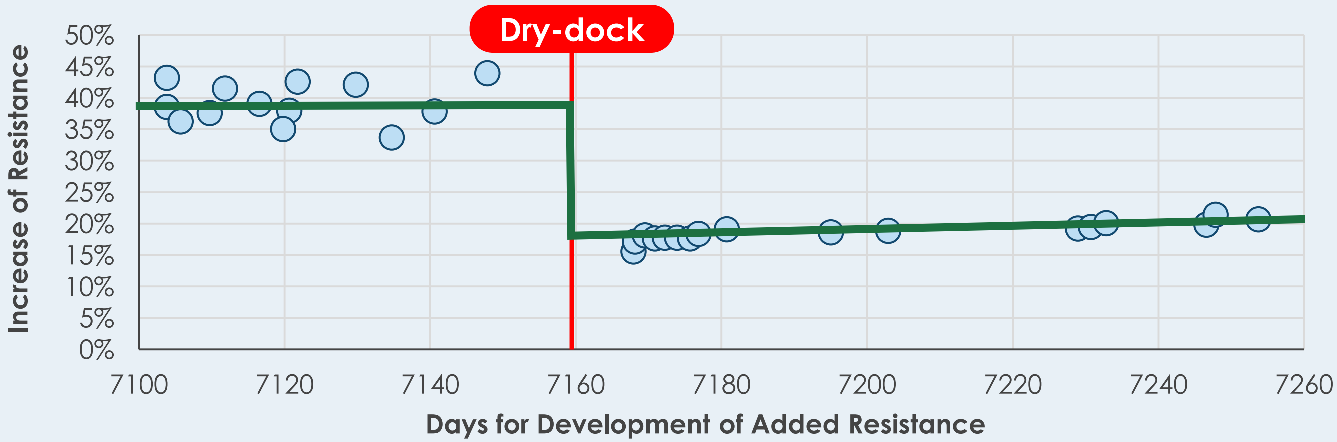
Post-docking Analysis (sisters)

(low cost hull pre-treatment = higher resistance outdocking)

18%

Resistance

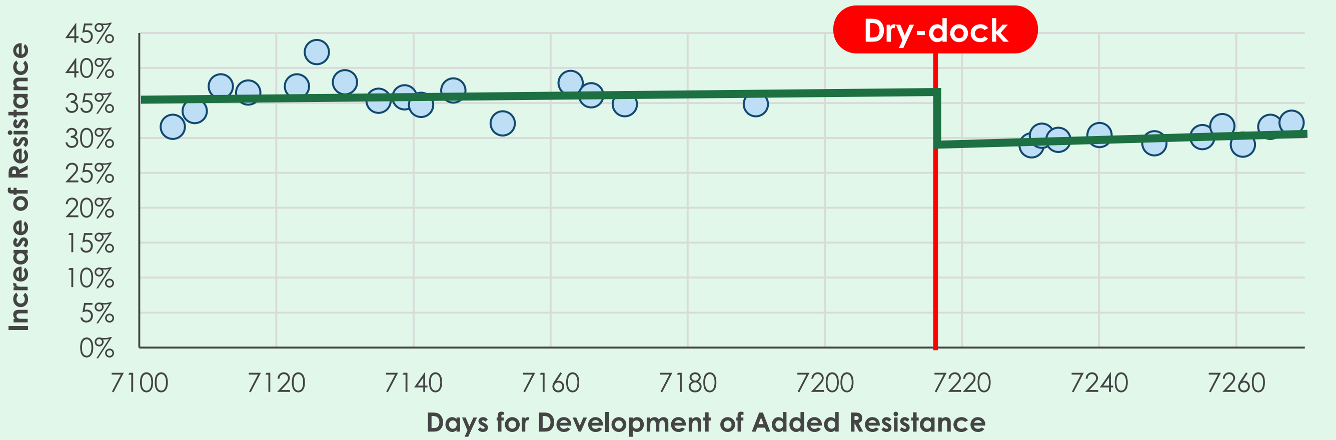
‘50% blast’



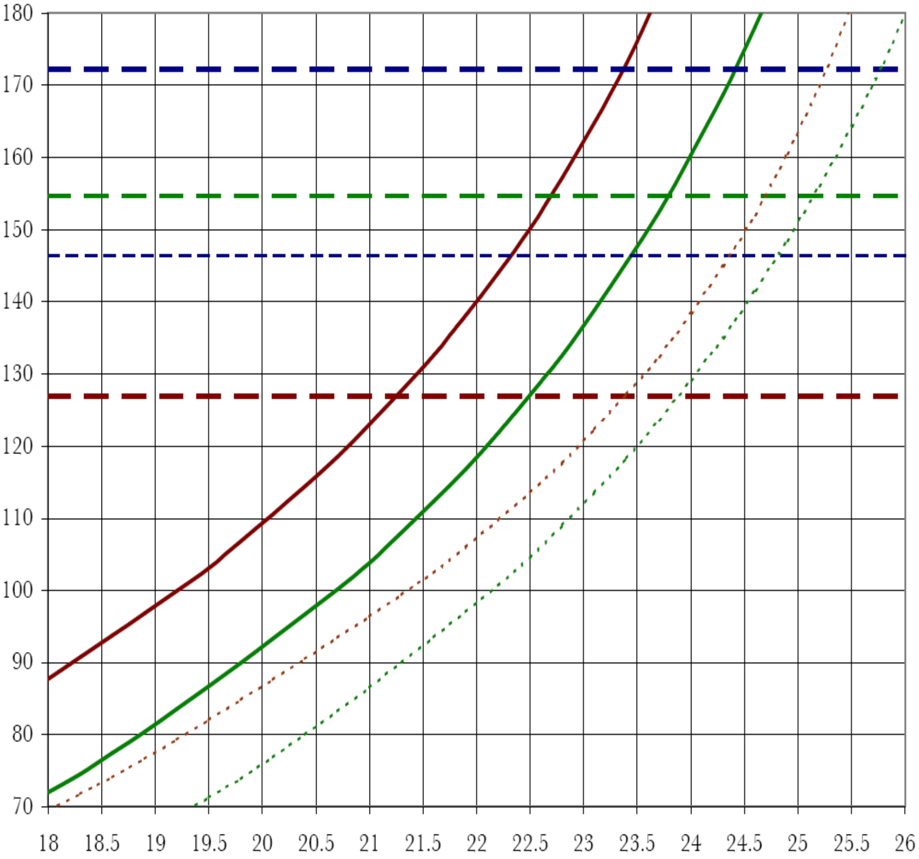
30%

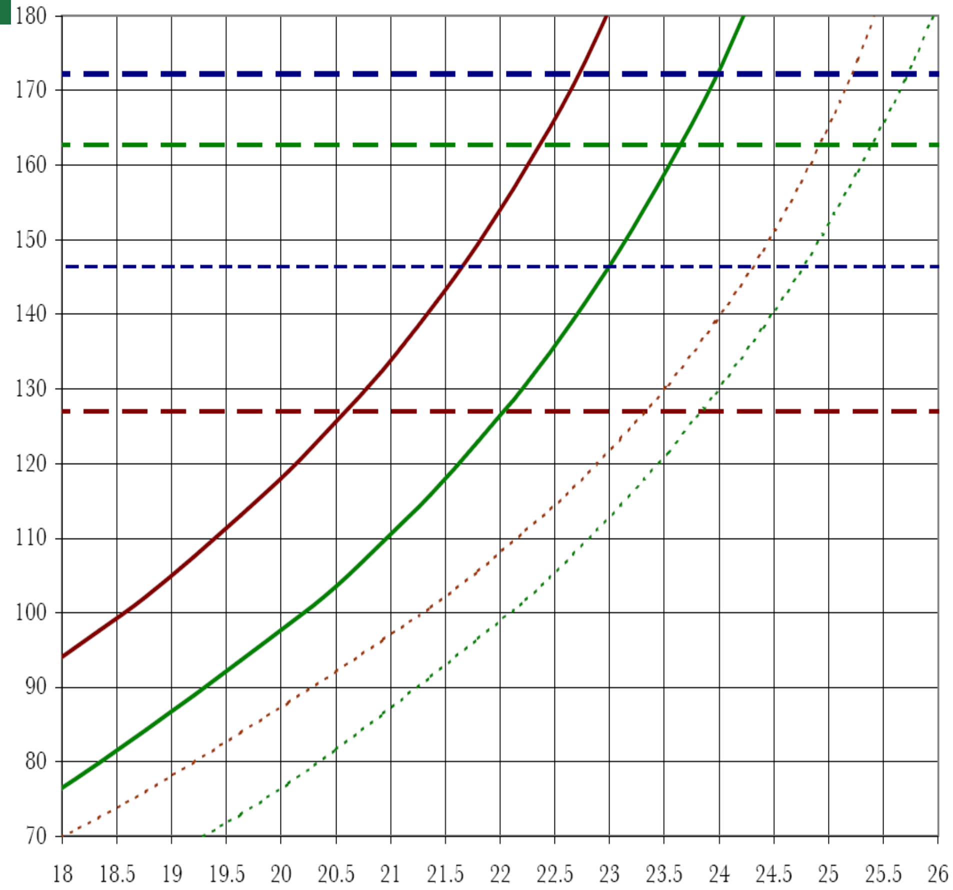
Resistance

‘10% blast’



18% (added resistance) 30%





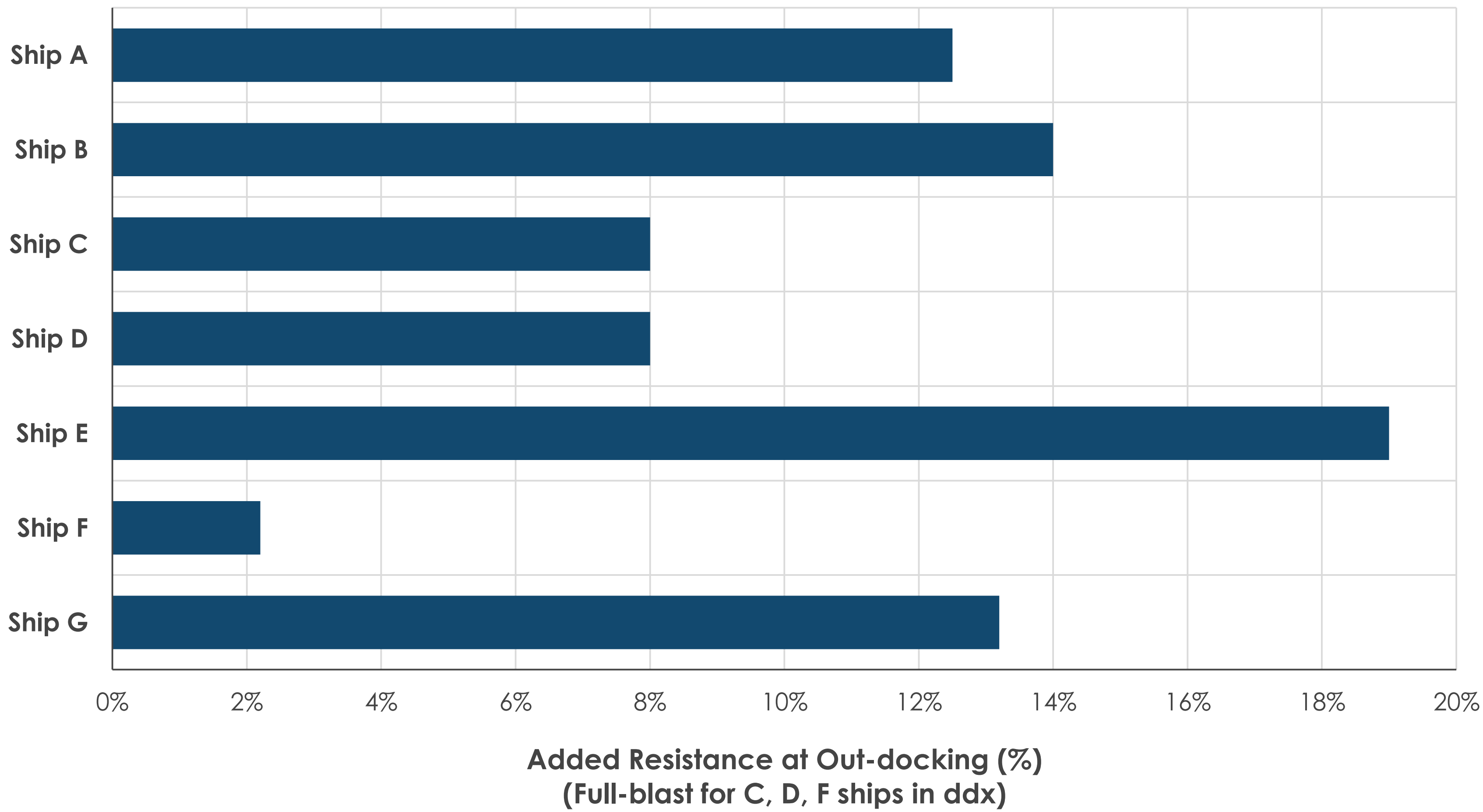
At 22 knots: 140 tons/day Trials 110 tons

At 140 t/day: 2 knot loss from trials

At 22 knots: 154 tons/day (14 tons more)

At 154 t/day: 2.5 knot loss from trials

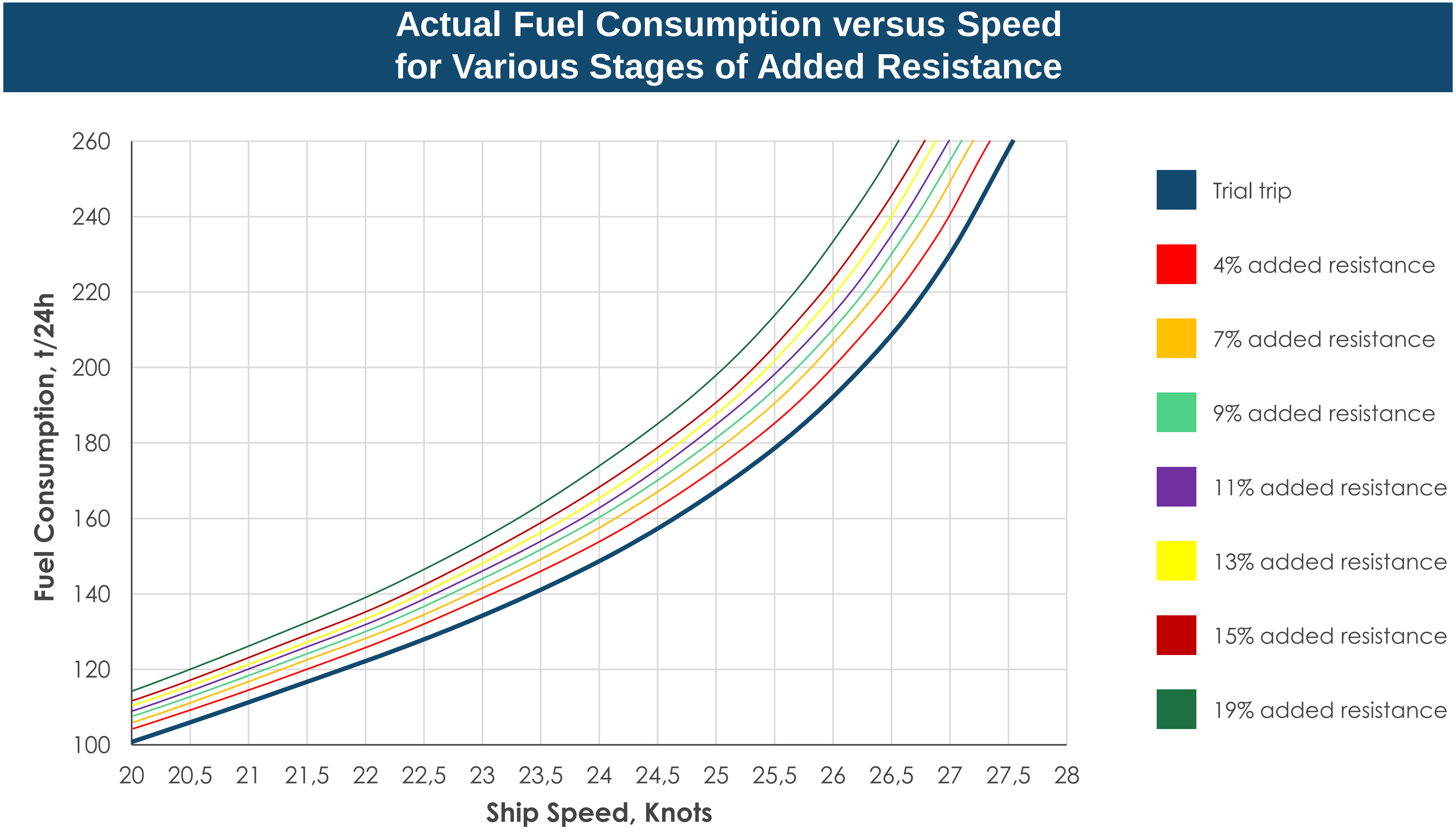
Intensive blasting produces better results



Blasting area and fuel efficiency

Vessel	Dry Dock	Age in Years (apprx.)	Blasted Area (sq m)			Total Areas (sq m)			Blast Area	Improve. in Resist (%)	Decrease in FOC
			Botm	Vert	Total	Botm	Vert	Total		(from CASPER)	(MT/24hr)
Ship A	13 mo	**6 yrs**	1183	1960	3143	3500	6500	10000	31%	**28%**	31.0
Ship B	10 mo	**5yrs**	1183	2800	3983	3500	6500	10000	40%	**33%**	30.0
Ship C	22 mo	**5 yrs**	600	3360	3960	4304	8149	12453	32%	**47%**	35.0
Ship D	38 mo	**8 yrs**	75	2163	2238	4304	8149	12453	18%	**27%**	20.0
Ship E	14 mo	**6 yrs**	632	2691	3323	6324	13452	19776	17%	**14%**	28.0

Effects of hull and prop resistance



4. Shared benefits

Latest information to be presented at conference

Ways forward

Develop a technical strategy for the hull / prop performance monitoring or *outsource to experts*.

Conduct a super polish in-water after docking to ensure no contamination of propeller blades;

Many small sand blasted spots is not optimal, rather make a total ‘square off’ of full blast of bad areas; Pay special attention to the area between full draft and ballast draft, as this area is highly exposed to the environment and susceptible to roughness and fouling;

Hull coatings cannot be judged solely on their inwater hydrodynamic resistance, as cost of coating, capacity to be cleaned, nontoxic aspects and other factors need to be assessed by shipowner.

Monitor the hull and propeller performance before and after DD and clean when the resistance has reached the level where gentle cleanings will save fuel but not damage the coating.

Q&A

THANK YOU !

DANKESCHON !