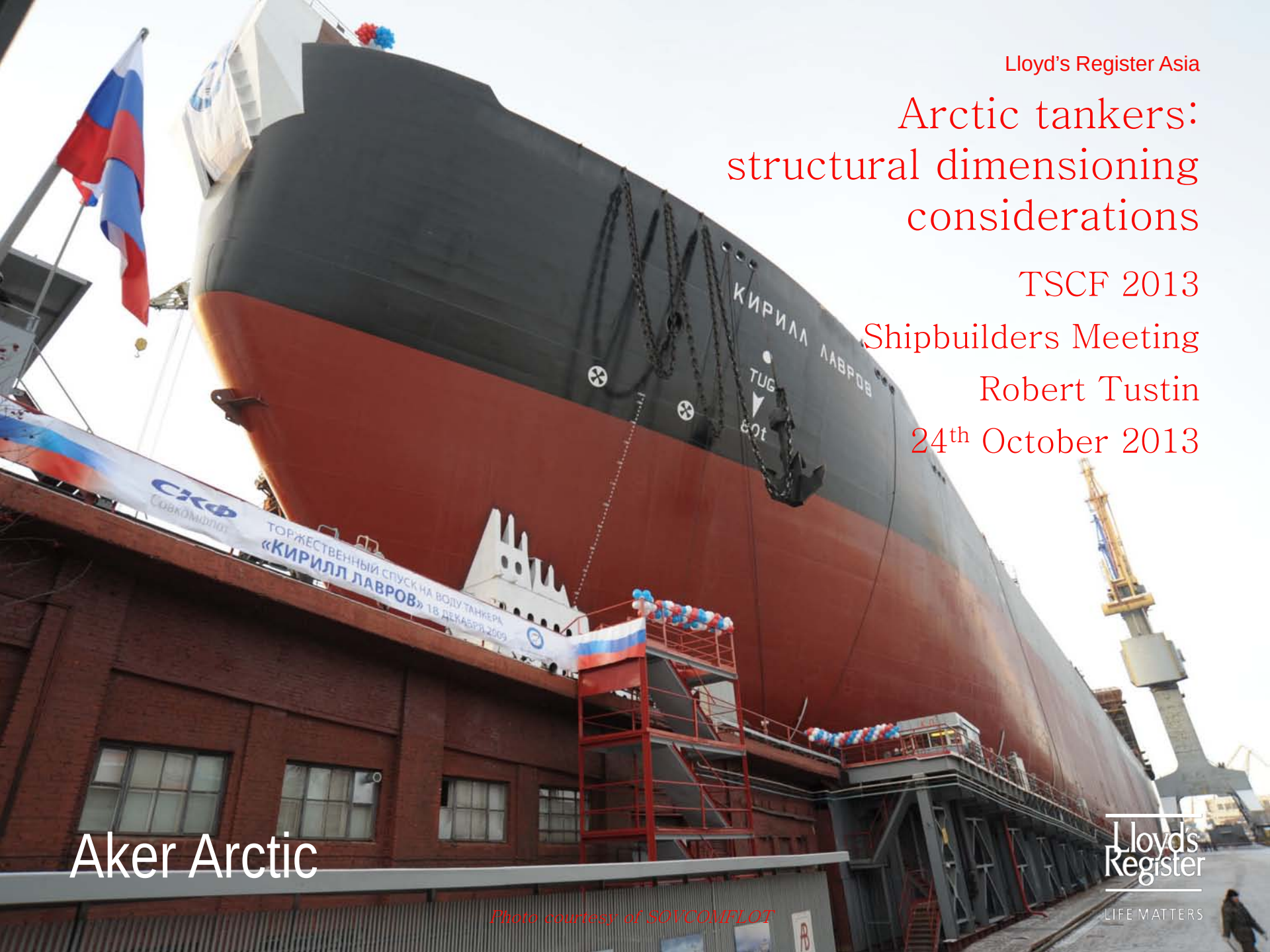

Lloyd's Register Asia

Arctic tankers: structural dimensioning considerations

TSCF 2013

Shipbuilders Meeting

Robert Tustin

24th October 2013

Aker Arctic

Photo courtesy of SOVCOMFLOT

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Presentation agenda

- Development of Arctic tanker fleet
- Selection of parent ship design for case study
- Case study findings:
  - Ice belt extents: LU6 and PC5
  - Ice belt plating: PC5 and PC4
  - Ice belt framing: PC6 and PC6
  - Primary structure by direct calculations
- Ice class notional equivalents and case study equivalency
- Summary of case study

Three phases of tanker development in Russian Arctic

- 1st Phase in 1970s and 1980s;
  - Soviet era seasonal arctic re-supply trade
- 2nd phase from mid 1990s to about 2002;
  - Russian Arctic seasonal oil export trade
  - Two series of small, 16 and 20K tonnes dwt Arctic tankers
  - Seasonal loading from SAL mooring offsho
- 3rd phase from 2008 to date;
  - Year round oil export trade from Russian A
  - Two series of 70k tonnes dwt Arctic tanke

Courtesy of Murmansk Shipping

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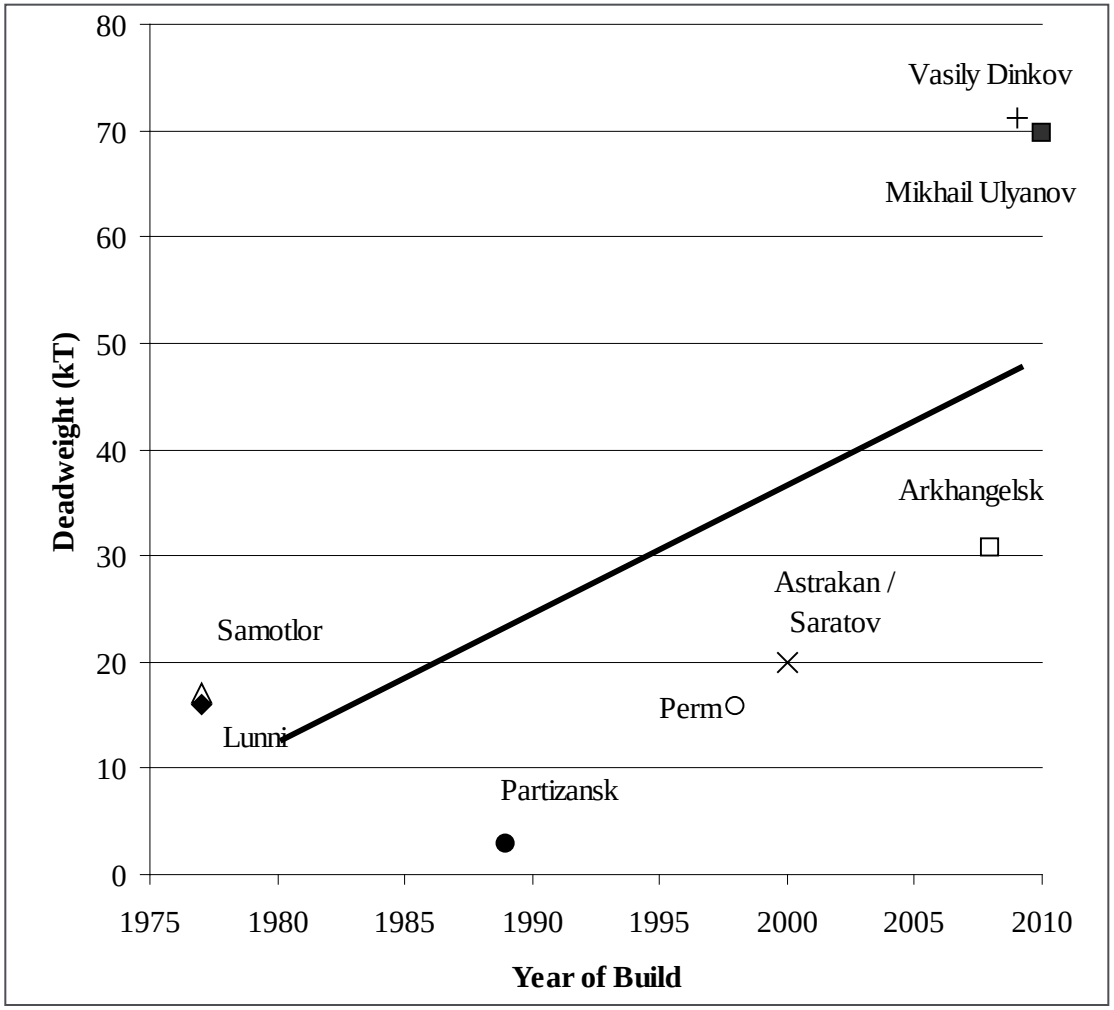
Arctic Tanker fleet deadweight trend



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Selection of the case study parent ship

A built ship and one of the largest Arctic tankers in service

Where past experience and proven practices of designer adopted

courtesy of Sovcomflot

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Parent ship design for case study

- Parent ship design requirements:
  - Dimensioned to RS ice category LU6 *(Arc6)*
  - Transversely framed ice belt
  - Designed for stern first operation in ice
- Using parent ship design the case study considered application of IACS PC Rules
- Case study purpose to understand the implications of application of IACS PC rules to a large Arctic tanker

courtesy of Sovcomflot

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Comparison of ice belt extents: bow and mid-body

- Parent ship design requirement
  - Ice strengthening to be dimensioned to RS ice class LU6 *(Arc6)*
- Issue identified:
  - Differences in ice strengthening extents between IACS PC and RS rules
- Key study finding:
  - Different approaches to define ice strengthening regions between rule-sets

Parent ship design requirement ***(RS ice category rules)***	**Outcome from IACS PC Rule application to Parent ship design**	**Description of issue identified in case study**	**Background or study conclusion on reason for issue arising**
Requirement for ice strengthening to be dimensioned to RS ice class LU6 *(Arc6)*	Comparison of extent of bow and mid-body ice belt regions for RS ice category and IACS PC rules	There are differences in ice strengthening extents for PC rules c.f. RS rules for bow and mid-body regions: • Extent of bow region in PC rules is much larger than RS rule application • Extent of shoulder region is different in PC rules than RS rules with different distribution of areas • No separate bilge area in PC Rule mid-body region	Two rule sets use different approaches to define ice strengthening zones or regions.

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Comparison of ice belt extents: stern

- Parent ship design requirement
  - Stern ice strengthening to be dimensioned as a bow to RS ice class LU6
- Issue identified:
  - Differences in ice strengthening extents between IACS PC and RS rules
- Key study finding:

Parent ship design requirement ***(RS ice category rules)***	**Outcome from IACS PC Rule application to Parent ship design**	**Description of issue identified in case study**	**Background or study conclusion on reason for issue arising**
Parent ship design is equipped with podded propulsion units and designed for stern first operation in ice. Requirement for stern ice strengthening to be dimensioned as a bow to RS ice class LU6 *(Arc6)*	Comparison of extent of stern ice belt region for RS ice category and IACS PC rules	For *"stern as a bow"* rule application there are differences in ice strengthening extents for PC rules c.f. RS rules for stern region: • Extent of stern region ice strengthening reflects the bow extents according to RS LU6 rules. • Extent of bow intermediate region in PC rules is much smaller and results in mid-ship region extending further aft than with RS rule application	Two rule sets use different approaches to define ice strengthening zones or regions.

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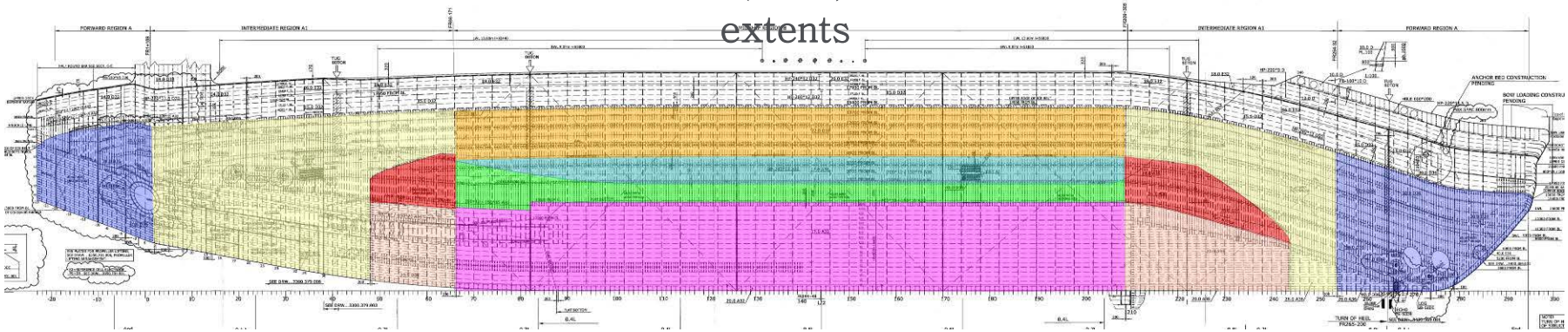
Comparison of ice belt extents: LU6 and PC5

RS LU 6 *(Arc6)* ice belt extents

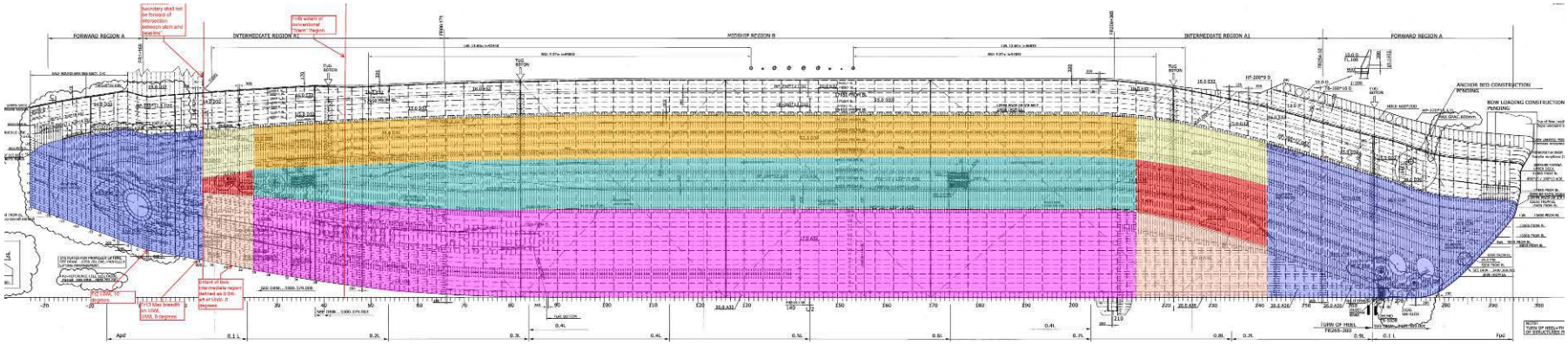


Stern as a bow: very different

PC rule no separate bilge area in mid-body region

Shoulder region extents different

PC rule bow extent longer



PC5 ice belt extents

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Comparison of plating thicknesses: PC5 requirements

- Parent ship design requirement
  - Ice belt to be dimensioned to RS ice class LU6 *(Arc6)*
- Issue identified:
  - Parent ship design non-compliant with PC5 requirements
- Key study finding:
  - Ice belt plating thickness differences when determined PC rule-set

Parent ship design requirement *(RS ice category rules)*	**Outcome from IACS PC Rule application to Parent ship design**	**Description of issue identified in case study**	**Background or study conclusion on reason for issue arising**
Requirement for ice strengthening to be dimensioned to RS ice class LU6 *(Arc6)*	Comparison of plating thicknesses in ice belt dimensioned to RS ice category LU6 *(Arc6)* and IACS PC requirements	The parent design dimensioned to RS ice category LU6 complies with IACS PC5 plating requirements except: • Area of bottom forward plating which is within 1 mm of IACS PC5 requirement • Areas where of "*overlap*" of ice strengthening by PC rules when compared with RS rules	Comparable pressures and plating formulations however plating thicknesses different between RS and PC Rules due to: • Variations in ice pressure loads • Different ice load patches

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Comparison of plating thicknesses: PC4 requirements

- Parent ship design requirement
  - Ice belt to be dimensioned to RS ice class LU6 *(Arc6)*
- Issue identified:
  - Parent ship design non-compliant with PC4 requirements
- Key study finding:
  - Ice belt plating thickness differences when determined PC rule-set

Parent ship design requirement ***(RS ice category rules)***	**Outcome from IACS PC Rule application to Parent ship design**	**Description of issue identified in case study**	**Background or study conclusion on reason for issue arising**
Requirement for ice strengthening to be dimensioned to RS ice class LU6 *(Arc6)*	Comparison of plating thicknesses in ice belt dimensioned to RS ice category LU6 *(Arc6)* and IACS PC requirements	The parent design dimensioned to RS ice category LU6 complies with IACS PC4 plating requirements except: • Areas of bottom forward and aft plating *(for "stern as a bow")* • Areas of bow, mid-body and stern plating which are within 1 mm of IACS PC4 requirement. • Areas where of "*overlap*" of ice strengthening by PC rules when compared with RS rules	Comparable pressures and plating formulations however plating thicknesses different between RS and PC Rules due to: • Variations in ice pressure loads • Different ice load patches

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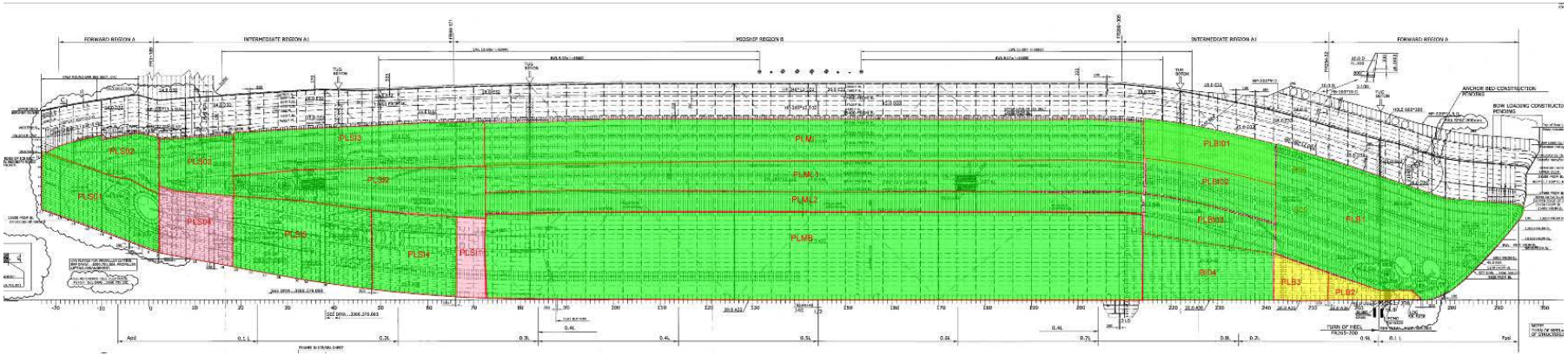
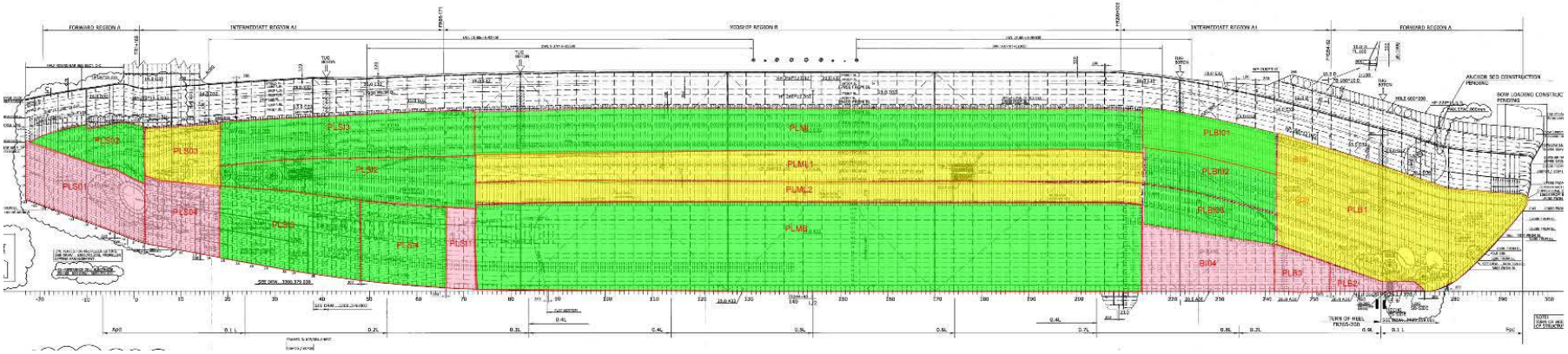
Comparison of ice belt plating: PC5 and PC4 rules



PC5 plating assessment



PC4 plating assessment

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Comparison of framing: PC6 requirements

- Parent ship design requirement
  - Transversely framed ice belt dimensioned to RS ice class LU6 *(Arc6)*
- Issue identified:
  - Parent ship design non-compliant with PC6 requirements
- Key study finding:
  - Ice belt framing requirements based on different proportions in PC rule-set

Parent ship design requirement ***(RS ice category rules)***	**Outcome from IACS PC Rule application to Parent ship design**	**Description of issue identified in case study**	**Background or study conclusion on reason for issue arising**
Requirement for ice strengthening to be dimensioned to RS ice class LU6 *(Arc6)* Requirement for transversely framed ice belt	Comparison of framing in ice belt dimensioned to RS ice category LU6 *(Arc6)* and IACS PC requirements	The parent design dimensioned to RS ice category LU6 complies with IACS PC6 framing requirements except: • Bilge frames which fail PC rule stability criteria • Areas where of "*overlap*" of ice strengthening by PC rules when compared with RS rules • Stern bottom frame which fail PC rule shear area requirements	Parent ship design stiffeners tend to pass PC rule modulus and shear area criteria, but fail the PC rule stability check. Framing requirements for PC rules based on stiffener profiles of entirely different proportions to those of RS rules

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Comparison of framing: PC5 requirements

- Parent ship design requirement
  - Transversely framed ice belt dimensioned to RS ice class LU6 *(Arc6)*
- Issue identified:
  - Parent ship design non-compliant with PC5 requirements
- Key study finding:

Parent ship design requirement *(RS ice category rules)*	**Outcome from IACS PC Rule application to Parent ship design**	**Description of issue identified in case study**	**Background or study conclusion on reason for issue arising**
Requirement for ice strengthening to be dimensioned to RS ice class LU6 *(Arc6)* Requirement for transversely framed ice belt	Comparison of framing in ice belt dimensioned to RS ice category LU6 *(Arc6)* and IACS PC requirements	The parent design dimensioned to RS ice category LU6 complies with IACS PC5 framing requirements except: • Lower ice belt and bilge area in mid-body where differing extents apply between PC and RS rules • Ice belt and lower ice belt in bow and bow intermediate areas where differing extents apply between PC and RS rules • Longitudinally framed bottom areas *(except mid-body)*. • Ice belt in stern due to higher loads from *"stern as a bow"* application	Parent ship design stiffeners tend to pass PC rule modulus and shear area criteria, but fail the PC rule stability check Framing requirements for PC rules are based on stiffener profiles of entirely different proportions to those used in Parent ship design compliant with RS ice category requirements

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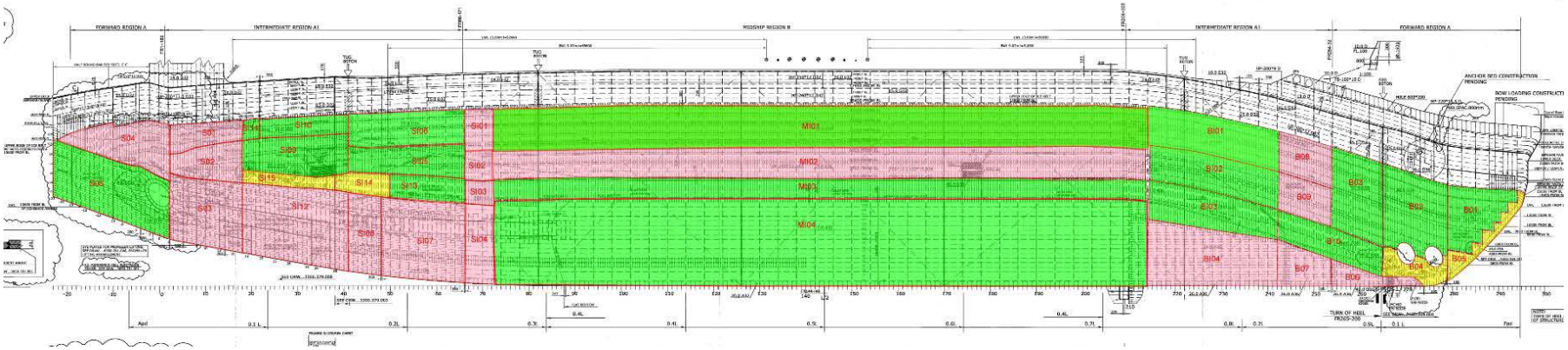
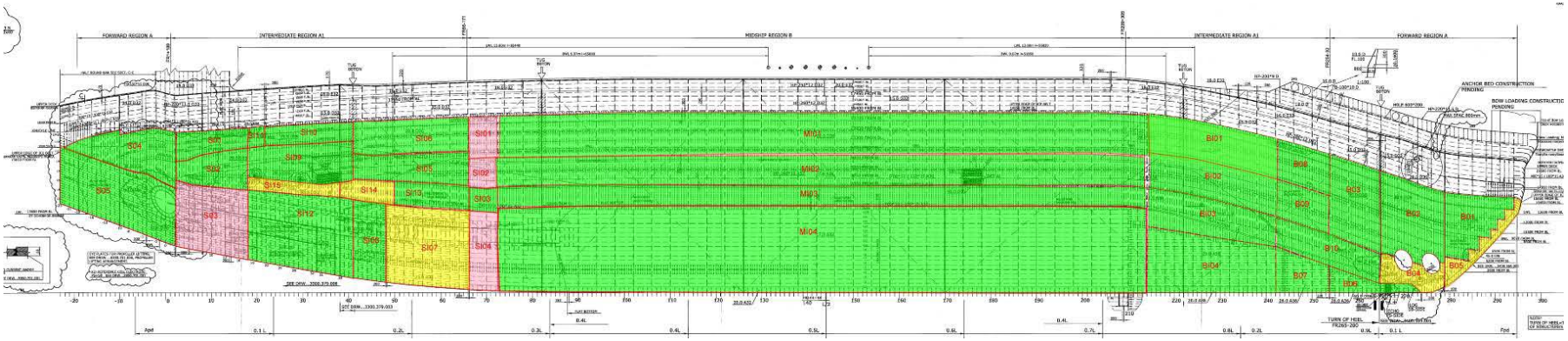
Comparison of ice belt framing: PC5 and PC6 rules



PC5 framing assessment



PC6 framing assessment

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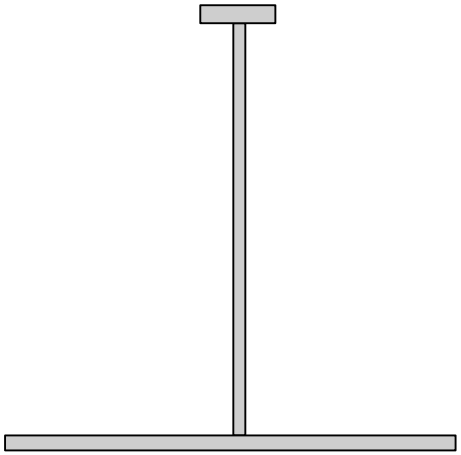
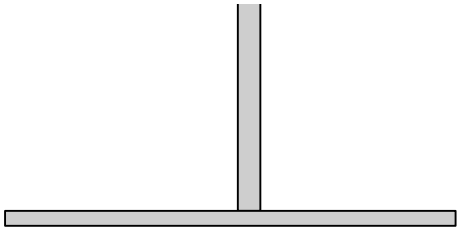
Stiffener profile considerations

- PC rules *'prefer' squat* frames typically used in Canadian practice as opposed to *slender* frames more typical of Russian build practice
- Dimensioning of framing using PC rules will result in squat frames with large web thicknesses
  - Can achieve compliant frame of equivalent area with iterations
- Care needed to select PC compliant frame sections which also satisfy design and production aspects



slender



squat

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Primary structure verification by direct calculations

- PC rules require primary structure *(web frames, stringers)* to be verified by direct calculations using ice load patch

- Using available FE model of parent tanker mid body area evaluated *(ice stringer, side web and bottom floor)*
  - Ice stringer does not meet PC5 requirement *(just fails)*
  - Side web frames exceed PC3 requirements
  - Bottom floors fail PC3 requirements
    (note: PC3 is first polar class with requirements for mid ship bottom area)

- In general higher strength of primary structure dimensioning using RS rules

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Ice class: notional equivalents

Parent ship design →

RMRS	PC
Arc4	PC7
Arc5	PC6
Arc6	PC4/PC5
Arc7	PC3
Arc8	PC2
Arc9	PC1

← Notional equivalence

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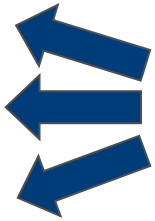
Ice class: case study equivalency

Parent ship design →

RMRS	PC
Arc4	PC7
Arc5	PC6
Arc6	PC4/PC5
Arc7	PC3
Arc8	PC2
Arc9	PC1



Case study equivalency

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Summary of case study

- Parent ship design ice belt is dimensioned to RS ice category LU6 (Arc6)
- Case study indicated that parent ship design is not compliant with any single Polar Class *(PC6/5/4/3)*
- Differing extents of rule application would require a re-design of the ice strengthening distribution

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Some learning from case study …

- For large Arctic tankers care is needed when applying ice class rules:
  - All ice class rules have limited application experience to large ship sizes
  - Applying two sets of ice class rules *(RS and PC)* to a large Arctic tanker has given very different results
  - Validation of rules themselves is understood to have used available cases of smaller ships with high Arctic ice classes such as icebreakers

- Dimensioning using rule sets which have yet to be validated with service experience requires different approaches for designers:
  - Should we be using Rules as a basis for design or a design check?

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